

Food and Nutrition as natural immune-boosters: An Elaborative Review

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Abstract

Our body is provided with many mechanisms to protect itself from pathogenic invasion. One of those is our immune system which can be enhanced through a diet rich in nutrients that play an immunomodulating role in humans. Several foods contain components that stabilize the functioning of both our innate immunity (macrophages, NK cells, dendritic cells, neutrophils) and acquired immunity (T cells and B cells). This article reviews the published literature to identify a list of dietary ingredients that play a role in human immunity such as the production of immune cells, preventing any inflammatory responses, regulating gene expression, and preventing oxidation.

Keywords: *Immunity, Nutrition, Inflammation, Vitamins, Minerals.*

1. Introduction

The immune functions in healthy individuals are damaged by several factors and the deprivation of health is related to disruption of immune functions [1]. Nutritional deficiencies cause impairments in immune system development and have a negative effect on immune incompetence [2] that results in susceptibility to infection, [3] allergies and chronic inflammation [4]. Several health conditions that are the result of an impaired immune function like cancer, inflammation processes such as atherosclerosis, rheumatoid arthritis, bronchial asthma, cystic fibrosis, fibromyalgia have been known to be prevented and treated by components present in food [5]. Therefore, it has been suggested that components derived from certain foods included in the diet can improve the immune functions in healthy people. The consumption of foods that provide such nutritional components not only stabilizes immune functions but also reduces the occurrence of pathogenic infection [1]. The Macronutrients (lipids such as n-3 PUFA) and micronutrients (zinc, vitamin D, and vitamin E), in addition to phytochemicals and functional foods (probiotics and green tea), may benefit the immune system when taken in appropriate amounts. Their immuno-modulating effects include inhibition of pro-inflammatory mediators, promotion of anti-inflammatory functions, modulation of cell-mediated immunity, alteration of APC function, and communication between the innate and adaptive immune systems [6]. Also, nutritional factors modulate metabolic processes which may include the activation or inhibition of key enzymes or immunoregulatory mediators that can result in altered cellular immune function, particularly in cells of T lymphocytes lineage [7]. Several trace elements and vitamins, have an important role in key metabolic pathways and immune cell functions [8]. Food containing vitamins like C, E and beta-carotene need to be added to our diet as they show defence mechanism against free radicals [9].

2. Role of Vitamins and Minerals in Human Immune system

2.1 Vitamins

Vitamin A

Vitamin A enhances growth, reproduction, blood cell formation, and improves the body's immune response. β -carotene and retinol are the precursors of vitamin A. β -carotene functions as an antioxidant that enhances the immune response. The retinoic acid derivative of retinol enhances the proliferation of lymphocytes and T-cells at the site of inflammation or the infection in the gut [10]. It is essential to competent innate responses. Deficiency of vitamin A has been associated with a reduced number of and activity of natural killer cells and eosinophils and diminished phagocytic and oxidative burst capacity of macrophages and neutrophils [11].

Vitamin B complex

B Vitamins are thought to work together as a “B complex.” Folate, Vitamin B₁₂, Vitamin B₆ aid in the maintenance of both innate and adaptive responses [12]. Vitamin B₁₂ required to make red blood cells and immune cells [10] and responsible for cell division and cell growth that plays an important role in the immune system [13]. It is important in erythrocyte production and cellular proliferation. Its deficiency leads to impaired neutrophil function [11] and also white blood cells cannot mature and multiply [13]. Supplementation of Vit B12 showed an improvement in antibody function and lymphocyte production [11]. Deficiency in Vitamin B₆ has been shown decreased number, function, and proliferation of immune cells, including T lymphocytes and also a decrease in antibody production. Furthermore, inhibition of cytokine release has been found in vitamin B6-depletion [12].

Vitamin C

Vitamin C has antioxidant properties through this it regulates the immune system and its role in collagen synthesis which is required for stabilization of epithelial barriers. It has an immunostimulant effect on lymphocytes and impacts the phagocytic function. Leukocytes have a high concentration of vitamin C and it is rapidly used during any infections [14]. Supplementation of vitamin C improves the function of the human immune system, such as antimicrobial and natural killer cell activities, lymphocyte proliferation, chemotaxis, and delayed-type hypersensitivity. It helps in neutralizing the reactive oxygen species formed in immune cells otherwise it could lead to the destruction of immune cells [10].

Vitamin D

Vitamin D consists of two main groups D2 and D3. Vitamin D3 plays an important role in regulating the human immune response. Activated macrophages can also produce the vitamin D metabolite 1,25-dihydroxy cholecalciferol (1,25 (OH)₂D) and the presence of vitamin D receptors (VDR) on immune system cells particularly on B cells, T-cells and antigen-presenting cells indicate important roles for 1,25-(OH)₂D in modulating the immune response, immune cell differentiation, and cell proliferation [14]. It modulates the inflammation that may lead to many chronic diseases [10]. Its deficiency is associated with autoimmunity and increased susceptibility to infection [13]

Vitamin E

Vitamin E has an immunoregulatory function and plays an important role in enhancing the immune response by inactivating and inhibiting free radicals. Due to the Vitamin E intake, there is an increased T-lymphocyte multiplication and cytotoxic cell activity [10]. It also increases natural killer cell toxicity and when given with vitamin C promotes phagocytosis [11]. Vitamin E showed an increase in the cell division and IL-2 producing capacity of naive T-cells and also showed improvement of effective immune synapse formation in naive T cells and the initiation of T-cell activation signals. It also seems to modulate the Th1/Th2 balance [15].

2.2 Minerals

Zinc

Zn is required for the optimal functioning of both innate and acquired immunity. Its deficiency leads to an increase in fungal, viral, bacterial infections, a decrease in the thymus gland and lymphocyte number, also leads to diarrhea, malabsorption, and physical impairment [9]. Zn deficiency causes diarrhea which is linked to the deteriorated

immune system and intestinal mucosal cell transport. It is known to show both anti-inflammatory and antioxidant activity [14]. It acts as a catalyst and regulates enzymes, proteins, and transcription factors and is, therefore, an important trace element in immune responses. It increases the secretion of IL-1 and has an antagonizing effect on toxic metals such as nickel that suppress the immune system [7].

Selenium

Se is involved in biological functions due to its integration into selenoprotein which is involved in the activation, proliferation, and differentiation of cells that bring about innate and adaptive immune responses. Dietary consumption of Se and selenoproteins is important for initiating or enhancing immunity, and are also involved in immunoregulation. This helps in preventing autoimmunity or chronic inflammation [16]. It plays an important role in reduction-oxidation regulation and antioxidant activities. It also protects individuals from the heart-damaging effects of the cytomegalovirus [13].

Copper

It has been proposed that Cu plays a role in leukocyte differentiation, maturation, and proliferation. Studies show that Cu reduces the individual's susceptibility to bacterial agents [17]. Mild to moderate deficiency of Cu causes a reduction in Interleukin 2 and T cell proliferation [13].

Iron

Iron is proposed to have a role in innate immune responses. It enhances immunity due to its presence as metalloenzymes or proteins such as iron catalase and lactoferrin (iron transporting protein in blood serum). It reduces the risk of diarrheal problems and morbidity [7]. The genes/proteins which are involved in iron homeostasis also have related immunological functions [18].

Iodine

In in-vitro studies, Iodine works with phagocytic cells to kill bacteria and promotes the synthesis of IgG through human B lymphocytes. The deficiency of Iodine leads to immunodeficiency and cancers due to antioxidant mechanisms [19].

Chromium

The trivalent form of Chromium (Cr III) has notable immune functions including the production of IgG, IgM Immunoglobulins, leucocyte blastogenesis, and synthesis of cytokines ((IL-1, IL-6, TNF- α in vitro and in vivo). Cr deficiency includes impaired glucose tolerance, elevated circulating insulin, glycosuria, fasting hyperglycaemia, impaired growth, elevated circulating cholesterol and triglyceride concentrations, decreased insulin receptor number, and impaired humoral immune response [20].

2. Foods with immunity-enhancing properties

There are several scientific reports of different types of foods that have shown to boost our immune system by either directly causing an immune response or by contributing a nutritional element that leads to an increased immunity. Below are such examples.

Vegetables

Vegetables are requisite to human nutrition because they provide us with nutrients such as dietary fibre, vitamins and minerals, and non-nutritive phytochemicals including phenolic compounds, flavonoids, bioactive peptides, etc. [21]. The phytochemicals present in fresh vegetables have anti-inflammatory, enzyme-inhibiting, and bioactive mechanisms that are capable of fighting oxidant activities [22]. Table 1 summarizes a list of common vegetables and their important nutrients [114].

Solanaceae

This family includes vegetables like tomato, eggplant, bell peppers.

Tomato

Tomato consists of vitamins like A, E, and C which are high powered antioxidants, minerals like K, P, Mg, and Fe that are required for nerves and muscle activities. It contains high amounts of lycopene which is a vital antioxidant [23]. Tomatoes consist of alpha, beta, gamma, and sigma carotene [24] and lutein that helps in the reduction of muscular degeneration. Lycopene in tomato can modulate intercellular gap junctions and hormonal immunity systems and metabolic pathways [25].

Eggplant

Chlorogenic acid, a major phenolic compound in the eggplant provides many health benefits such as antioxidant, anti-inflammatory, cardioprotective, anti-obesity, and anti-diabetic properties [26]. Glycoalkaloids present in eggplant show anticancer activities. They also possess anti-inflammatory function and are known to lower blood cholesterol [27].

Bell Peppers

Bell peppers are a good source of Vitamin C which promotes immune health. They contain moderate-high levels of flavonoids which are known to show anti-oxidative, anti-inflammatory, and anti-allergy properties [28]. Several health benefits of consuming Bell peppers are: clearing the lungs and sinuses, protecting the stomach by increasing the flow of digestive juices, triggering the brain to release endorphins (natural painkillers), neutralizing cavity-causing acids, and protect the body against cancer through their antioxidant activity [29].

Cucurbitaceae

Cucurbits are good sources of carotenoids, ascorbate, folate, potassium, and phenolics [30]. They show biological activities like cytotoxic, hepatoprotective, cardiovascular, anti-inflammatory, analgesic, and antiproliferative activity. Their flavonoids and phenolic extracts showed cell proliferation enhancement, immunomodulation, antioxidant, anti-allergic, and anti-inflammatory activities [31].

Apiaceae

This family is rich in fatty oils and proteins, these include carrots, celery, parsley, coriander, and dill [32]. It is a good source of dietary fibers and minerals like molybdenum. Carrots are rich in carotenoids, polyphenols, and vitamins that act as antioxidants, anticarcinogens, and immune enhancers [33]. As carrots are rich in pro-vitamin A it can enhance immunity system and tissue maintenance [34].

Brassicaceae/Crucifers

Brassica family includes red and white cabbage, Brussels sprouts, cauliflower, turnip, broccoli, Chinese cabbage, kale, Pak choi, and oilseeds. Brassica vegetables consist of antioxidants such as vitamin C, E, carotenoids, and antioxidant enzymes like catalase, superoxide, and peroxidase. They can also stimulate the immune system, decrease the risk of cancers [35]. Bioactive compounds of brassica can reduce inflammation by activating detoxification of enzymes, removal of free radicals, and inducing immune functions. Isothiocyanates are the phenolic compounds of brassica that slow down many inflammation activities [36].

Broccoli contains nutrients that possess anti-cancer properties, such as Di-indolyl methane and small amounts of Selenium. The 3, 3-di-diindolylmethane found in broccoli is a potential modulator of the innate immune response system having antiviral, anti-bacterial, and anti-cancer activity [37]. A phytochemical sulforaphane exhibits a protective effect against acrolein-induced inflammatory damage in peripheral blood mononuclear cells and also suppresses pathways that produce pro-inflammatory cytokines thereby proving its anti-inflammatory function [38].

Alliums

These have many health benefits such as anticancer, antimicrobial, antiplatelet, antithrombotic, antihyperlipidemic, antihypertensive, anti-asthmatic, and immunostimulatory [39]. Includes vegetables mainly onion and garlic.

Onion

Onion contains several biological components and phenolic compounds such as flavonoids, particularly quercetin derivatives. Due to the presence of these compounds, it is known to possess antiviral, antifungal, antibacterial, antioxidant, anticarcinogenic and antimutagenic, anti-thrombotic, and anti-hyperglycaemic activities, prebiotic

character, and immunosuppressive, neuroprotective, and anti-inflammatory effects [40]. Onion is considered as a mucus clearing food and is used for treating cold, cough, bronchitis, and influenza [41].

Garlic

The bioactive compound diallyl sulphide (DAS) of garlic can inhibit inflammatory factors such as reactive oxygen species (ROS), NF- κ B (nuclear factor kappa-light-chain-enhancer of activated B cells), and the expression of COX-2 via the NF- κ B pathway where N- κ B is required for cytokine production and cell survival. Based on human studies in invitro and in vivo, garlic has antithrombotic activity, inhibits platelet aggregation [42]. It's shown that garlic or its compound induces a variety of immunomodulatory activities in leukocyte cytokine production [43].

Legumes (Fabaceae)

The incorporation of legumes into our diet offers protection against chronic diseases [44]. They include peas, beans, and lentils and are good sources of Vitamin B1, B2, B3 and B6 and minerals such as Ca, Cu, Mg, Zn, Fe, K and P. Legumes help in prevention and treatment of diseases such as, diabetes mellitus, cardiovascular diseases, cancer (e.g. breast and prostate cancers) and lowering of blood cholesterol levels [45].

Beetroot (Amaranthaceae)

Beetroot contains several bioactive compounds that provide anti-anaemic, anti-inflammatory, anti-hypertensive, antioxidant, anticarcinogenic, antipyretic, antibacterial, detoxicant, and diuretic properties. Carotenoids present in beetroot act as antioxidants, anticarcinogens, and immune-enhancers [46]. Red beet provides phytochemicals that stimulate the hematopoietic, immune system, kidney, and liver protection [47]. Betalains present in beets are shown to reduce the protein levels of the proinflammatory cytokines TNF- α , IL-6, IL-8, and IL-1 β , the reactive oxygen and nitrogen species levels [48].

Sweet potato (Convolvulaceae)

Sweet potatoes are rich in dietary fibers, vitamins like pro-vitamin A, B2, C, and E that are rich antioxidants and minerals like K, Na, Mg, Ca, and Mn. It consists of high levels of lutein that helps in macular degeneration. It boosts the immune system and helps to prevent infections and diseases [49]. Purple sweet potato polysaccharides showed immune-enhancing activities [50].

Mushrooms

The immune-modulating functions of mushrooms are due to the presence of several bioactive compounds including polysaccharides especially β -D-glucan, polysaccharide-peptide/protein complexes, proteoglycans, proteins, and triterpenoids. Beta-D-glucan isolated from mushrooms were found to stimulate NK cells, T cells, B cells, and macrophage-dependent immune system responses [51]. Besides, they are reputed to possess anti-allergic, anti-cholesterol, anti-tumour, and anti-cancer properties [52].

3.2 Fruits

The several anti-oxidant compounds such as poly-phenolic flavonoids, vitamin-C, and anthocyanins present in fruits protect the human body from oxidative stress, remove free radicals from the body, thereby offering protection against cancers, aging, infections, etc and develop the capacity to fight against these ailments by boosting our immunity levels [53]. Table 2 summarizes a list of common fruits and their important nutrients [115].

Citrus Fruits (Rutaceae)

Consumption of citrus fruits including oranges, lemons, lime, and grapefruits is considered a natural means to protect against Cancers due to the presence of Vitamin C and other components which are folic acid, carotenoids, dietary fibres, potassium, selenium, and a wide range of phytochemicals[54]. Naringin, a flavonoid present in citrus fruits, has an anti-inflammatory effect on inflammatory cytokines [55]. Lemon contains D-Limonene which supports the immune system. It also has antioxidant activity thereby preventing several cancers and cardiovascular diseases. Oranges are rich in Vitamin A & C and help fight infections, cold, and flu [56]. Grapes contain antioxidants and phytochemicals that have an anti-allergic, anti-inflammatory, anti-microbial, as well as anti-cancer activity. Lime's anti-oxidant properties protect eyes from aging and macular degeneration and they cure fever and infections of the respiratory system [53].

Papaya (Caricaceae)

Papaya is a good source of vitamin A, C, B1, and B2, thiamine, folate, riboflavin, niacin, calcium, potassium, iron, and fiber contents and low in calories but rich in vitamins and minerals [57]. It consists of carotenoids mainly beta carotene, lycopene, enzymes like papain and chymopapain and antioxidants like vitamin C and β -carotenoids reduce the severity of the conditions such as asthma, osteoarthritis and rheumatoid arthritis[58]

Kiwi (Actinidiaceae)

It consists of three commercially used fruits kiwi (Actinidiaceae *deliciosa*), golden kiwi (*A. chinensis*), and hardy kiwi (*A. arguta*) [59]. Kiwi is rich in vitamins, especially vitamin C and B8, carotenoids, dietary fiber, and antioxidants. The high content of vitamin c and polyphenols which have anti-inflammatory effects regulates the immune system by reducing the risk of flu [60]. In vitro results showed that golden kiwi can influence the immune system by regulating the cells and cytokinesis [61].

Banana (Musaceae)

Bananas contain vitamins like A, C&D along with Vitamin B6 that are necessary for producing antibodies and red blood cells and aid our immune system [62]. It helps in decreasing homocysteine levels within the body and protects our body against chronic disease conditions [53].

Dates (Arecaceae)

Dates contain several phytochemicals that possess antioxidant activity, cholesterol-lowering properties, and other potential health benefits such as chemoprevention of cancer, prevention of diabetes, and cardiovascular diseases [63]. They are rich in carotenoids that prevent chronic ailments. Besides, its anti-infective, anti-inflammatory and anti-haemorrhagic properties make it a health-promoting food [53].

Amla (Phyllanthaceae)

It is rich in vitamin C, flavonoids, and is a good source of antioxidants and other health benefits. Amla has shown immunomodulatory activities and anti-inflammation response. Ellagic acid i.e. present in amla is a powerful antioxidant [64]. Amla shows natural killer cell activity and antibody-dependent cellular cytotoxicity. It has been demonstrated to be effective in the treatment and prevention of cancer as it has applications of neuromodulatory, chemo modulatory, chemo preventive effects, free radical scavenging, and antioxidant, anti-inflammatory, antimutagenic, and immunomodulatory properties [65].

Berries

Berries have vitamins A, C, and E, and the B complex vitamins. They boost the immune system, reduce inflammation, and also have antioxidant properties. The consumption of berries has potential health benefits rich in micro and macronutrients and bioactive compounds like flavonoids and ellagic acid [66]. Related to berries and their compounds human trials showed some beneficial effects like reduction in the proliferation and development of premalignant or malignant tissue, maintenance, and enhancement of gut bacteria, and boosting adaptive immunity [67].

Pomegranate (Lythraceae)

It is considered the most powerful antioxidant fruit from others. Its consumption prevents aggregation of platelets that is the main risk factor for cardiovascular diseases. It also helps in promoting smooth digestion, bowel movements, weight reduction, and in boosting body immunity [53]

Other fruits

Apples from Rosaceae family help prevent and cure several ailments like IBS, Arthritis, constipation, and help protect the immune system from several cancers. Apricots (Rosaceae) help normalize vision, promote proper immune system function, reproduction, and have antioxidant activity. Avocado, Pineapple, Guava, and Pears contain Vitamin C and are powerful antioxidants boosting the immune system. Figs are rich in natural benzaldehyde and act as an anti-tumour agent; thus it can kill pathogens, fungus, and viruses in the human body. Eating Jackfruit increases the body's immunity to cough, cold, and flu [53].

3.3 Whole grains(WG)

The incorporation of whole grains in our diet has shown to prove to have health benefits. They contain not only B vitamins and dietary fiber, but also other health-promoting components including starch, inulin, beneficial fatty acids,

fermentable carbohydrates, phytochemicals like antioxidants and aligning(phytosterols) [68]. WG help improves metabolic diseases by favoring bacteria and metabolites involved in controlling the host immunity, appetite, lipogenesis, gluconeogenesis, gut barrier, and oxidant stress [69]. Whole grains lower the risk of non-communicable diseases such as cardiovascular disease, diabetes, metabolic syndrome, and certain cancers. Examples of healthy WGs include wheat, rice, barley, corn, rye, oats, millets, and sorghum [70].

3.4 Meat, Eggs & Fish

Red Meat

Consumption of red meat provides minerals such as Iron, Zinc, selenium, potassium, and vitamins B6 and B12. It also provides long-chain omega-3 polyunsaturated fatty acids that are essential for a healthy immune system. Selenium acts as an antioxidant and is necessary for immune system function [71]. It is a major source of protein, providing about 20 g/100 g of beef or lamb consumed. It contains conjugated linoleic acid (CLA) that has been found to modulate immune functions in humans [72].

Eggs

Eggs are one of the most abundant forms of dietary protein. They contain a variety of bioactive proteins in their white part, namely ovalbumin, Ovo transferrin, ovomucin, lysozyme, and avidin. These proteins exhibit antibacterial and immunoprotective properties. The other bioactive components in eggs such as phospholipids, cholesterol, lutein, zeaxanthin, show a variety of pro- and/or anti-inflammatory properties [73].

Fish

Fish provides tremendous amounts of protein, Polyunsaturated Fatty acids (PUFAs), and is poor in saturated fat. PUFAs inhibit the production of inflammatory mediators such as eicosanoids, pro-inflammatory cytokines, chemokines, adhesion molecules, platelet-activating factor, and reactive oxygen and nitrogen species [6]. The Omega-3-fatty acids in it have shown anti-inflammatory and immunogenic functions. They are even helpful in treating autoimmune diseases like rheumatoid arthritis [74].

3.5 Dairy

Dairy products such as fermented milk and skimmed yogurt made from unpasteurized milk, yogurt, and turkey cheese are abundant with natural yeast. They ferment the undigested plant fibers and convert them into chemicals that enter into the bloodstream and help strengthen the immune system. They provide other health benefits such as lowering cholesterol, which reduces the risk of heart disease [75]. Milk is known to contain several biopeptides including vitamins, minerals, special proteins [76]. Prolactin in milk increases lymphocyte and thymocyte trafficking, and immune development. Immunoglobulins IgA and IgG are present that modulate humoral immune responses. Peptides and protein hydrolysates obtained from milk caseins and major whey proteins exhibit immunomodulatory effects including lymphocyte proliferation, antibody synthesis, and regulation of cytokines [77]. Frequent consumption of yogurt intake has been shown to prevent the risk factors for cardiovascular disease, to lower diabetes risk, enhance the development of host immunity, and to lower the risk for dysbiosis and chronic kidney disease [78]. Curd promotes the health of individuals by boosting their immune system. It strengthens natural immunity by stimulation of mucosal and systemic host immunity, including activated macrophages, increased levels of immunoglobulins, higher levels of NK cell activities, and cytokines in the host body [79].

3.6 Probiotics

Probiotics are live microorganisms, which when consumed, confer a health benefit on the host [80]. The various effects of probiotics on our immune system can be [81] -

1. Probiotic bacteria promote the endogenous host defence mechanisms.
2. They have enhanced humoral immune responses, particularly intestinal IgA responses, and thereby promote the intestine's immunologic barrier.
3. They stimulate nonspecific host resistance to microbial pathogens, and thereby aid in immune elimination.
4. They modulate the host's immune responses to potentially harmful antigens with the potential to down-regulate hypersensitivity reactions.

3.7 Teas/Herbal Teas (*Theaceae*)

Tea preparations act as antioxidants and their extracts exhibit chemo preventive effects on cancers, cardiovascular diseases, and inflammation [82]. The phytochemical L-Theanine in tea boosts immunity by enhancing the disease-fighting potential of Gamma Delta T cells. Besides Thearubigins and Theaflavins are the other types of phenols present in tea that show antioxidant activity and are known to treat several ailments [83]. Catechins (epicatechin, epigallocatechin, epicatechin gallate, and epigallocatechin gallate) are its active ingredients in tea. Among these, epigallocatechin-3-gallate (EGCG) is abundant in Green Tea which has high antioxidant capacity. EGCG increases the production of immunoregulatory cytokines, prevents the risk of several cancers, and suppresses inflammations preventing cellular damage [84]. Herbal teas are not derived from the tea plant (*C. sinensis*) but are a mixture of several combinations of dried leaves, seeds, grasses, nuts, barks, fruits, flowers, or other botanical elements. They could contain chamomile, ginseng, cinnamon, cardamom, parsley, ginger root, clovers, etc. Each of these elements has immune-enhancing properties including antitumor, antioxidant, anti-inflammatory, antiviral, antibacterial, etc. which prove beneficial to our health [85].

3.8 Spices and Herbs

Zingiberaceae

The commonly used species of the *Zingiberaceae* family are Turmeric (*Curcuma longa*) and ginger (*Zingiber officinale*).

Turmeric

Turmeric consists of bioactive compound curcumin. It can regulate various biological activities, transcription factors, signal transducers, mitogen-activated protein kinase, cytokines release, and the receptors on different immune cell types, thus these actions affect the innate and adaptive immunity mainly pathological conditions. Curcumin powerfully modulates the function of immune cells like B cells, dendritic cells, monocytes, macrophages, and neutrophils [86]. It has an antioxidant property where it acts as a scavenger of oxygen free radicals and it can also protect haemoglobin from oxidation and interferes in the replication of microbes and viruses, therefore, increases the body's immune system's ability to fight the infection due to its antimicrobial and antioxidant activities [87].

Ginger

Ginger is an appetite enhancer, improves digestive system, anti-cold, analgesic, and anti-inflammatory [88]. Red ginger which has bioactive compounds that are superior to normal ginger showed promising results as immunomodulators in Psoriasis by affecting the lymphocyte T activity [89].

Piperaceae

This family is a source of natural products with a wide range of biological activities [90] and black pepper belongs to this family which has antioxidant and antimicrobial potential and gastroprotective modules. These are rich in vitamins A and K in addition to dietary fiber [91]. The bioactive compound piperine can downregulate the inflammatory pathways and it can protect against oxidative damage [92] and it has been considered as an immunomodulator by downregulating Th2 cytokines [42]. It also functions as a bioavailability enhancer as it has an efficient permeation through the epithelial barrier in the intestine and therefore enhances absorption of specific nutrients, drugs, and also bioactive compounds like curcumin and tea phenols [92].

Lauraceae

It consists of a wide range of spices such as the bay leaf, cinnamon, etc. Extracts of cinnamon have shown to attack major respiratory and gastrointestinal tract pathogens in vitro [43]. Cinnamon and its extracts are antioxidants and regulate insulin action, therefore it can be beneficial in the control of glucose tolerance and diabetes. The bioactive compound cinnamaldehyde has an anti-inflammatory effect on gastric inflammation by inhibiting NF-kB activation and reduces allergic encephalomyelitis in vivo by regulating T-cells [92].

Myrtaceae (Cloves)

Clove possesses several therapeutic properties such as antidiabetic, anti-inflammatory, antithrombotic, anaesthetic, pain-relieving, and it is a popular remedy for respiratory disorders, sore throat, and headache. Clove could suppress T cells and their functions and promote B cell expansion and function, and humoral responses [93]. The major ingredients present in clove that are shown to modulate immune responses are eugenol (50–87%), eugenyl acetate, tanene, thymol, and cariophyllene, although the mechanisms of effect remain unclear [94].

Apiaceae

Apiaceae family consists of a wide range of spices like cumin, coriander, fennel, etc.

Coriander

Apart from showing hypoglycaemic, hypolipidemic, antibacterial, antimutagenic activity, coriander possesses antioxidant properties due to the presence of active phenolic acid compounds, including caffeic and chlorogenic acid, flavonoids including quercetin, kaempferol, rhamnetin, and apigenin. These compounds inhibit free radicals in the cellular system when they are obtained through the diet [95]. It is rich in vitamin A, B2 (riboflavin), C and dietary fiber, they also contain the spice-based compound, linalool reduces the effects of trauma on the immune system [96]. Coriander can prevent oxidative stress-related diseases and along with a combination of drugs can be used in the treatment of cancer [32].

Cumin

Cumin is used in traditional medicine for digestive disorders. It is nutritionally rich with monosaturated fats, protein, and dietary fibers and also consists of vitamins B and E and several minerals like iron. It possesses immunostimulatory, gastroprotective, hepatoprotective, nephroprotective, hepatoprotective, nephroprotective, and neuroprotective activities [97]. Flavonoids of cumin like apigenin and luteolin showed antioxidant activity [98]. It has free radical scavenging and metal chelating activity to protect biomolecules [32].

Black cumin

It is also known as the black cumin which is rich in nutritional values. It consists of dietary fiber, unsaturated, and essential fatty acids. The protein of black seed consists of eight essential amino acids out of nine essential amino acids. It is also a source of carotenoids and minerals like Ca, Na, Fe, and K. Drs. El-kadi and Kandil in 1986 conducted a study with human volunteers to know the effect of black seeds on the immune system where they observed an increase in natural killer cell's functional activity and also a maintained ratio between helper T-cells and suppressor T-cells. Black seeds have anti-inflammatory activity, anti-tumour activity and it also has anthelmintic activity against tapeworm [99].

Fennel

Flavonoids of fennel like quercetin, rutin, and isoquercitrin showed immunomodulatory activities. It is an excellent source of antioxidants [98]. Fennel has inhibitory effects on acute and subacute inflammation diseases and also type IV allergic reactions [32].

Flaxseed (*Linaceae*)

Flaxseeds are rich in vitamins especially A, C, E, and F and minerals like P, Mg, K, Na, Fe, Cu, Mn, and Zn. Arginine and glutamine are abundant in flaxseed proteins that play an important role in the prevention and treatment of heart diseases and support the immune system [100]. It is one of the best sources of omega 3-fatty acids that can alter T helper cell balance by inhibiting cytokine production which in turn inhibits immunoglobulin E synthesis and T helper 2 cell differentiation [101]. Flaxseeds are considered as a potent nutraceutical and functional food [100]. The antioxidant property of flax seeds showed a reduction of total cholesterol and also platelet aggregation [101].

3.10 Nuts

Nuts are good sources of vitamins E and B-complex groups along with minerals like Ca, K, P, Mg, Fe, Zn, and antioxidant minerals such as Mn, Cu, and Se. Besides, they also contain antioxidant compounds. Several health benefits of nuts include improvement of digestive function, memory, and metabolism, boost the immune system, aid in weight loss, help manage diabetes, protect against different types of cancer, viral and fungal infections [102].

Almonds (*Rosaceae*)

The main nutrients found in almonds that modulate immune and inflammatory processes include monounsaturated and polyunsaturated fats, vitamin E primarily as α -tocopherol, flavonoids (catechin, epicatechin, kaempferol, isorhamnetin), and plant sterols [103]. Almonds possess anti-inflammatory action against CVD and the presence of Vitamin E imparts an antioxidant action in the body [104].

Cashews and Pistachio (*Anacardiaceae*)

Cashew kernels contain vitamin B, a naturally occurring antioxidant with immunity-boosting power and consuming Cashew kernels during cold and flu season is known to improve one's immunity. Selenium in cashews protects against

Cancers and Vitamin E in it increases immunity against aging processes [105]. Pistachios are rich in Mg which helps to prevent osteoporosis, diseases of the nervous system, and immune system. The increased levels of tocopherol in pistachio prevent heart disease, LDL-oxidation, diabetes, and cancer and promote the immune system [106].

Walnuts (*Juglandaceae*)

Walnuts are abundant in Omega-6 and Omega-3 polyunsaturated fatty acids which are essential dietary fatty acids. The main health benefits of walnut kernels include lowering cholesterol, reducing inflammation, and improving arterial function. It contains high levels of Arginine that prevent platelet adhesion and aggregation. It helps against CVD, Cancer, Polycystic ovary syndrome (PCOS), and Diabetes [107]. Walnuts are called inflammation-fighters and help prevent inflammatory ailments like RA [102].

Peanuts (*Fabaceae*)

Peanuts contain polyphenols, isoflavones, phytosterols, resveratrol which are strong antioxidants. Regular consumption of peanuts has been associated with reduced risks of coronary heart disease (CVD), hypertension, inflammation, cancer, gallstones, age-related cognitive decline, and increased life expectancy [108].

4. Other factors influencing Immunity

The lifestyle of an individual lives affects his/her immune health to a large extent. The lifestyle in wealthy nations, including diet, is connected to a higher risk of chronic diseases, such as cardiovascular disease, colorectal cancer, and type II diabetes. This is because individuals in such nations consume highly refined, omnivorous diets of poor nutritional quality. Those diets are energy-dense, high in animal protein, total and saturated fats, and simple sugars but low in fruits, vegetables, and other plant-based foods [109]. The incorporation of a moderate form of exercise in the lifestyle has shown to help the immune functions. It has been even reported that exercise reduces the low-grade, systemic inflammation associated with obesity and sedentary life, by reducing the production of inflammatory cytokines [110]. Adequate hydration, specifically in the form of water contributed to good health. It has been proven that drinking sufficient amounts of water enhances the sedimentation of mucous membranes lining the respiratory tract, which helps in the production of antibodies and white blood cells, thereby strengthening the immune system's performance [75]. Studies have proposed that individuals that are properly hydrated show less fluctuation in the number of immune cells when exposed to environmental or physical stress as compared to those who were dehydrated [19].

5. Food costs and their effect on nutrition

In families with low income, the choice of food depends largely on food costs. Nutrient-rich foods are expensive per kilocalorie than foods having lower nutritional value and people tend to attract high calories and fat-containing food as they are more palatable and economical [111]. Though people are aware of healthy food choices, in comparison to the choice dimensions of price and taste, they may opt for the tastier and cheaper, but less nutritious food [112]. However, people should realize that higher consumption of fruit and vegetable has a major role in lowering the risk of heart diseases and stroke and in lowering the total death rate. Replacement of fats and sweets with fruits and vegetables is a general public health recommendation [113].

How can we ensure that healthy diets are followed by individuals globally on a low budget? We can select certain foods that have a good ratio of nutritional quality to price. Examples include pulses, nuts, oils, and whole-grain cereals and animal products like milk and eggs are all considered foods that are low cost but high on nutrition [111]. Prices of popular high-fat foods could be gradually increased and those with lower fat content could be modestly reduced, this policy could become a long-run idea to promote healthy food choices [112].

6. Conclusion

Consumption of the nutrient-rich food along with incorporating other activities in life like moderate exercise helps in maintaining our body's metabolism and immune system. However, overconsumption of any type of food should be

avoided and whatever is consumed should be done only at the recommended levels., for example, increased intake of oils, meats, etc. may lead to a greater risk of cardiovascular diseases, and certain foods like amla, peanuts, and dairy products cause allergies in some individuals. Instead of spending more money on unhealthy fast food, it should rather be used to incorporate healthy fruits and vegetables into the diet belonging to common families like *Brassicaceae*, *Rutaceae*, *Fabaceae*, *Solanaceae*, *Alliums*, etc. Therefore, it is recommended that we follow a balanced diet for the proper functioning of the body, and also check for both undernutrition and overnutrition to keep diseases away.

Table 1: Common Vegetables and their nutrient content
(Where Vitamin K in Micrograms(mcg) and all other nutrients in Milligrams(mg))

vegetables	Vit A	Vit B						Vit c	Vit E	Vit K (mcg)	Se	Zn	Cu	Fe
		B1	B2	B3	B6	B9	B5							
Tomato	0.3075	0.046	0.023	0.731	0.098	0.18	0.109	15.5	0.66	0.0097	-	0.21	0.073	0.33
Eggplant	0.0111	0.75	0.02	0.594	0.085	0.14	0.074	1.3	0.41	0.0029	0.0001	0.12	0.058	0.25
Bell peppers	0.0822	0.042	0.021	0.355	0.166	0.07	0.073	59.5	0.27	0.0055	-	0.1	0.049	0.25
Carrot	3.9858	0.051	0.034	0.503	0.119	0.11	0.181	2.8	0.8	0.0107	0.0002	0.3	0.052	0.27
Broccoli	0.3621	0.049	0.096	0.431	0.156	0.84	0.48	50.6	1.13	1.10	0.0012	0.35	0.048	0.52
Beetroot	0.009	0.023	0.034	0.281	0.057	0.68	0.123	3.1	0.03	0.2	0.0006	0.3	0.063	0.67
Sweet potato	4.256	0.122	0.121	-	0.326	0.07	1.008	22.3	0.81	0.0026	0.2	0.36	0.184	0.79

Table 2: Common Fruits and their nutrient content (where all nutrients expressed in milligram(mg))

Fruit	Vit A	Vit B1	Vit B2	Vit B6	Vit C	Vit K	Zn	Mg	Se	Fe	K
Banana	0.0228	0.037	0.086	0.433	10.3	0.0006	0.18	32	0.0012	0.31	422
Apple	0.0294	0.031	0.047	0.075	8.4	0.004	0.07	9	-	0.22	195
Grapes	0.0300	0.104	0.106	0.13	16.3	0.022	0.11	11	0.0002	0.54	288
Kiwifruit	0.0180	0.019	0.017	0.043	64	0.0278	0.1	12	0.0001	0.21	215
Orange	0.0885	0.114	0.052	0.079	69.7	-	0.09	13	0.0007	0.13	237
Pineapple	0.0288	0.13	0.053	0.185	78.9	0.0012	0.2	20	0.0002	0.48	180
Watermelon	0.4881	0.094	0.06	0.129	23.2	0.0003	0.29	29	0.0011	0.69	320
Lime	0.0102	0.02	0.013	0.029	19.5	0.0004	0.07	4	0.0003	0.4	68
Papaya	0.4596	0.038	0.045	0.027	86.5	0.0036	0.1	14	0.0008	0.14	360
Dates	0.0045	0.076	0.097	0.243	0.6	0.004	0.43	63	0.0044	1.5	964
Blueberries	0.0651	0.055	0.061	0.077	14.4	0.286	0.24	9	0.0001	0.41	114
Guava	0.3090	0.111	0.066	0.181	376.7	0.0043	0.38	36	0.001	0.43	688

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