Chapter 2

Role of Vegetables in Human Nutrition and Disease Prevention

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Abstract

Vegetables are important for human health because of their vitamins, minerals, phytochemical compounds, and dietary fiber content. Especially antioxidant vitamins (vitamin A, vitamin C, and vitamin E) and dietary fiber content have important roles in human health. Adequate vegetable consumption can be protective some chronic diseases such as diabetes, cancer, obesity, metabolic syndrome, cardiovascular diseases, as well as improve risk factors related with these diseases. In this chapter, basic information will be given about the classification of vegetables, preparation and cooking, and their effects on food content of vegetables and effects on health and diseases (diabetes, obesity, metabolic syndrome, cardiovascular diseases, and cancer).

Keywords: vegetables, diabetes, metabolic syndrome, cardiovascular diseases, cancer, cooking methods, phenolic compounds, antioxidants, fiber

1. Introduction

Vegetables are annual or perennial horticultural crops, with certain sections (roots, stalks, flowers, fruits, leaves, etc.) that can be consumed wholly or partially, cooked or raw [1].

Vegetables are important for human nutrition in terms of bioactive nutrient molecules such as dietary fiber, vitamins and minerals, and non-nutritive phytochemicals (phenolic compounds, flavonoids, bioactive peptides, etc.). These nutrient and non-nutrient molecules reduce the risk of chronic diseases such as cardiovascular diseases, diabetes, certain cancers, and obesity [2, 3].

In recent years, consumers began to change their eating patterns with the growing interest in the effect of foods in staying healthy and maintaining health. "Western" type diets are characterized by increased intake of calories, sugar, saturated fats and animal protein, and reduced consumption of vegetables and fruits. When this type of diet is combined with lack of activity, the prevalence and frequency of diseases such as obesity, diabetes, and cardiovascular pathologies also increases [3]. In healthy diets (Mediterranean diet model), eating plant-based foods such as fruits and vegetables, cereals, legumes and nuts, replacing butter with healthy oils such as olive oil and canola oil, using herbs and spices to add flavor instead of salt, limiting red meat to several times a month and eating fish and poultry at least twice a week are recommended. Evidence from epidemiological studies and clinical trials shows that the Mediterranean diet is associated with many positive health outcomes such as reduced risk of various chronic illnesses, reduced overall mortality, and increased likelihood of healthy aging[4].One of the most important features of these diets is the high consumption of vegetables, and therefore fiber, vitamins, minerals, flavonoids, phytoestrogens, sulfur compounds, phenolic compounds such as monoterpenes and bioactive peptides, which have positive effects on health [3]. In this chapter, basic information will be presented on the classification of vegetables, their relation to health, and the effects of preparation and cooking on nutrient content of vegetables.

2. Classification of vegetables

There are approximately 10,000 plant species used as vegetables in the world. Classification of these species can be done by considering a common set of features. It is important for food researchers, dietitians, and nutrition educators to subcategorize vegetables by taking into account health and nutrition. This sub-categorization will be more useful if it is based on similarities in food composition [5]. Vegetables can be classified according to the part of the plant used for nutrition and the specific nutritional value [6].

2.1. Green vegetables

2.1.1. Leaf vegetables

This group includes spinach, lettuce, curly lettuce, chard, purslane, chicory, etc. These are important minerals (iron and calcium), vitamins (A, C, and riboflavin) and fiber sources.

Young, fresh leaves contain more vitamin C than mature plants. The green outer leaves of lettuce and cabbage are richer in vitamins, calcium, and iron than white inner leaves. Thinner and greener leaves are more nutritious and usually have lower calories.

2.1.2. Stalk vegetables

The best examples to be given to stalk vegetables are celery and asparagus. They contain minerals and vitamins in proportion to the green color. Asparagus is a particularly rich source of folic acid.

2.1.3. Fruit and flower vegetables

Broccoli, cauliflower, and artichoke are frequently consumed flowering vegetables. Broccoli is a good source of iron, phosphorus, vitamins A and C, and riboflavin. Cauliflower is also a good source of vitamin C. The nutritional value of the outer leaves of cauliflower and broccoli is much higher than the flower buds. They can be consumed raw in salads or cooked. Artichoke is a good source of minerals, especially potassium, calcium, and phosphorus, and has high dietary fiber content. Tomatoes and peppers are the most common fruit vegetables. Both are rich in vitamin C. Other fruit vegetables include cucumber, zucchini, and eggplant. A dark green or yellow color indicates high β-carotene content. The darker the yellow color, the higher the content of β-carotene.

2.2. Root vegetables

2.2.1. Root, bulb, and tuber vegetables

Carrot, beet, turnip, fennel, onion, radish, and potato are examples of this group of vegetables. Yellow and orange varieties are rich in β-carotene, which is the precursor of vitamin A. Onion is an extraordinary example of root vegetables and contains moderate levels of vitamin C.

2.2.2. Legumes

This group includes legumes, peas, and soya beans. This group is rich in saponin and soluble fiber [6].

Subgroups may differ from country to country and classifications in nutritional guidelines are based on nutritional content in different countries. For example, the basic food guidelines used in the United States (Basic 7 and Basic 4 Food Groups and Food Guide Pyramid) are focused on dark green leafy and dark orange/yellow group vegetables for beta-carotene and citrus fruits for vitamin C. Later on, 2010 USDA MyPyramid food guide identified dark green leafy vegetables and broccoli, other leafy vegetables, legumes, unique vegetables (dark orange, tomato, allium vegetables, etc.) and additional vegetables [**Table 1**]. In the guide prepared by Turkish Ministry of Health (Turkey Nutrition Guide 2015), vegetables have been classified as *Dark green leafy vegetables* (Mediterranean/salad greens such as spinach, chard, quince, blackcurrant, vine leaf, curly, lettuce, spinach, purslane, parsley, cress, arugula, mint, sorrel, radish, dill, radica, and curly-chicory (chopped or in salads)), *other green vegetables* (broccoli, okra, fresh beans, fresh peas, green zucchini, artichokes, asparagus, brussels sprouts, varieties of pointed or stuffed peppers, cucumber, and iceberg lettuce (chopped or in salads)), *Red—orange—blue—purple vegetables* (tomatoes, carrots, red pepper, radish, winter squash, beet, aubergine, and red cabbage), *white vegetables* (onion, celery, cabbage, cauliflower, leek, mushroom, ground apple, turnip), and *starchy vegetables* (potatoes and fresh corn) [7].

Vegetable subgroups	Important sources[a]	Contributes[b]
Dark green leafy vegetables and broccoli	Vitamin C Vitamin K Folate Beta-carotene Lutein + zeaxanthin, flavones	Iron, copper, manganese Vitamin B6 Phytosterol Alpha-carotene Flavonols TAC
Other leafy vegetables	Vitamin C Vitamin K Anthocyanidins	Phytosterol Manganese Vitamin B6 Folate Beta-carotene Lutein + zeaxanthin TAC
Legumes	Copper Folate Phytosterol Flavan-3-ols Flavonols TAC	Dietary fiber Magnesium, iron, zinc, manganese Vitamin B6
Unique vegetables	Vitamin C Alpha-carotene lycopene	Vitamin B6 Vitamin K Manganese, copper Beta-carotene
Additional vegetables	Flavonoids	Vitamin C Vitamin K

[a]Provides >25% DRI or highest mean concentration of component per 100 g.
[b]Provides >10% DRI or second or third highest concentration of component per 100 g.

Table 1. Summary chart for food ingredients in 2010 my pyramid vegetable subgroups [5].

3. The effect of vegetables on some disease

3.1. Effects on diabetes, obesity, and metabolic syndrome

Diabetes mellitus (DM), obesity, and the metabolic syndrome (MS) are increasing health problems in recent years in parallel with the increase in unhealthy eating habits and unhealthy living behaviors. One of the most basic aspects of the control and management of the disease in individuals with these health problems is the regulation of eating habits. In medical nutrition therapy applied to these individuals, it is important to meet the energy and nutritional needs of individuals, as well as including foods with functional activities against the complications of these diseases in the diet. Phytochemical compounds (carotenoids, alkaloids, terpenoids, and phenolics), which are secondary compounds found in vegetables, are thought to be protective against these diseases.

3.1.1. Root, bulb, and tuber vegetables

Onions and garlic, thanks to the volatile oils, organosulfur compounds, and flavonoids in their content, are among the vegetables thought to be protective against DM, obesity, and MS [8]. Organosulfur compounds such as S-methyl cysteine and flavonoids such as quercetin in these vegetables exert a functional effect by regulating the activities of some enzymes involved in carbohydrate metabolism, increasing insulin secretion and sensitivity, and increasing NADP+ and NADPH activities [9]. In addition, these vegetables inhibit the enzymes α-glucosidase and α-amylase, inhibiting the formation of D-glucose from oligosaccharides and disaccharides and delaying the absorption of glucose from the intestines [10]. Onion and garlic are especially protective against dyslipidemia and oxidative stress, which are seen due to DM and MS.

Kumar et al. found that obese patients with Type 2 diabetes who used garlic tablets in addition to metformin had significantly higher fasting blood glucose (FBG), postprandial blood glucose, total cholesterol (TC), triglyceride (TG), low density lipoprotein cholesterol (LDL), C-reactive protein (CRP), and adenosine deaminase levels compared to those of patients using only metformin [11]. In dyslipidemic individuals with Type 2 DM, the use of garlic tablets for 12 weeks significantly decreased TC and LDL levels, while high-density lipoprotein cholesterol (HDL) levels were significantly increased [12]. Although there are similar studies suggesting that garlic has positive effects on blood glucose level and plasma lipid profile in the presence of DM [13], garlic was also found to increase antioxidant enzyme activities in DM and reduce bioactive aldehyde levels [14].

It was found that garlic consumption increased adiponectin levels in MS patients [15]. Considering that adiponectin has antiatherogenic and antiatherosclerotic effects [16], garlic consumption in MS patients is thought to be protective against cardiovascular diseases (CVDs). In addition, it has been determined that garlic has a positive effect on insulin resistance in rats with MS induced by high fructose content feed [17].

In obese rats induced by high-fat diets, garlic supplemented animal feed reduced TG and TC levels, as well as body weight and epididymal fat accumulation [18]. Similarly, in obesity induced rats with a high-fat diet, garlic reduced visceral and epididymal fat accumulation while reducing atherogenic index and cardiac risk factors [19].

It was reported that onion powder added to animal feed in experimental diabetic rats induced by aloxane or streptozotocin had a hypoglycemic effect [9, 20]. In a study comparing the efficacy of glibenclamide, which is an oral antidiabetic drug, with onion application at different doses in DM rats, it was reported that 300 mg/kg of onion extract application reduced fasting glucose levels by 75.4%, whereas 2.5 mg/kg glibenclamide reduced fasting glucose levels by 76.4% [21].

Studies investigating the effects of onion consumption in the presence of DM on antioxidant enzyme levels such as superoxide dismutase (SOD), catalase (CAT), and glutathione peroxidase (GSH-Px) showed that onion consumption increased the levels of these enzymes [22]. In these studies, it was also found that onion reduced bioactive aldehyde levels such as malondialdehyde (MDA) formed by the decomposition of lipid hydroperoxides.

It was reported that onion reduced insulin resistance and improved FBG levels in MS Zucker type rats [23]. It was shown that onion extract reduced weight gain, epididymal fat accumulation, and serum TC levels in BALB/c mice that were made obese with a high-fat diet [24]. It was reported that a daily onion consumption of 100–120 g significantly decreased TC and LDL cholesterol levels of obese women with polycystic ovary syndrome [25].

3.1.2. Leaf vegetables

Purslane and chard are green leafy vegetables thought to have functional activity against DM, MS, and obesity. Purslane shows a functional effect due to free oxalic acids, alkaloids, omega-3 fatty acids, coumarins, flavonoids, cardiac glycosides, anthraquinone, α-linolenic acid, and active compounds in its composition [26], while chard shows its effect via phospholipids, glycolipids, fatty acids (palmitic, stearic, oleic, and linoleic acid), folic acid, ascorbic acid, and pectin in its composition [27]. Purslane, described by WHO as one of the most used medical plants, is also called "global panacea" [28].

In studies investigating the effects of the use of purslane extract on anthropometric and biochemical changes in Type 2 DM patients, it was found that consumption of purslane extract significantly reduced HbA1c levels [29], TG, TC, LDL, FBG, and post-prandial blood glucose, body weight and BMI, whereas it significantly increased HDL levels [30]. In another study, consumption of purslane extract significantly increased glucagon-like peptide-1 concentrations, which has positive effects on beta cell proliferation and insulin secretion, in individuals with Type 2 DM [31].

In rats fed high-fat diets, it was seen that purslane decreased TG, TC, and LDL levels [32] and similarly it decreased TC and TG levels in hypercholesterolemic rats [33]. In rats with DM induced by streptozotocin, it was shown that purslane had hypoglycemic [34] and antioxidant effects [35].

In Type 1 diabetic rats, chard extracts were shown to reduce blood glucose levels and improve beta cell regeneration [27], while significantly decreasing adenosine deaminase levels [36]. It was also found that chard decreased elevated MDA levels due to diabetes and increased antioxidant capacity [36]. In Type 2 diabetic rats, chard extract was also shown to be effective in increasing insulin secretion and lowering blood glucose levels by increasing GLP-1 and acetylcholine levels [37]. It was also found to have a hypolipidemic effect in high fat diet-induced rats [38].

3.1.3. Fruit and flower vegetables

Broccoli and cauliflower are vegetables thought to have protective effects against many diseases thanks to glucosinolates and indole-3-carbinol they contain [39]. Indole-3-carbinol given to obesity induced mice by a high fat diet was shown to reduce epididymal fat accumulation, body weight, insulin, leptin, and blood glucose levels, increase adiponectin levels, and improve glucose tolerance [39]. Similarly, in Type 2 diabetic rats fed with a high fat diet, indole-3-carbinol reduced blood glucose levels, and HbA1c levels, thereby reducing thiobarbituric acid reactive substances, lipid hydroperoxides and conjugated dienes levels, and increased levels of SOD, CAT, and GSH-Px [40]. Positive effects of broccoli on impaired lipid profile due to high fat diets were detected [41].

3.1.4. Legumes

Leguminosae family peas and vegetables such as peas and soybeans inhibit alpha-amylase enzyme, and show antidyslipidemic and antioxidant effects thanks to phytosterols such as B-sitosterol, campesterol and stigmasterol, and linoleic acid they contain [42]. Studies conducted by Helmstädter revealed that different plant extracts of this family improved glucose tolerance and glycosuria [43]. Consumption of different species of this family such as Pinto beans, Great Northern beans, Navy beans, and Black beans have been reported to reduce the risk of obesity, MS, and DM [44].

3.2. Effects on cardiovascular diseases

CVDs are the primary cause of death and illness in the world. The Global Burden of Disease Study reported that 29.6% of all deaths in the world were due to CVDs [45]. The main factor in these deaths is the increase in unhealthy lifestyle and eating habits. Most of the risk factors associated with CVDs are reversible risk factors and non-pharmacologic measures such as healthy eating habits and healthy lifestyle changes may help control the risk factors for the disease. Increased consumption of vegetables, which are an important part of a healthy diet, has been shown to reduce CVD-related mortality rates [46] and improve risk factors [47]. Vegetables are protective against CVD thanks to low content of saturated fat, trans fat, and cholesterol and being rich in bioactive compounds such as flavonoids, phytoestrogens (lignans, coumestran, isoflavones, resveratrol, and lycopene), organosulfur compounds, soluble dietary fibers (β-glucan, pectin, and psyllium), isothiocyanates, monoterpenes, and sterols (sitostanol, stigmasterol, and campesterol) [48].

3.2.1. Root, bulb, and tuber vegetables

Epidemiological studies indicate that there is an inverse relationship between garlic consumption and CVD development. Studies in the literature reported that garlic and garlic components show cholesterol and lipid lowering effects by inhibiting key enzymes involved in cholesterol and fatty acid synthesis (monooxygenase and HMG-CoA reductase) [49], antiplatelet effect by inhibiting cyclooxygenase enzyme activity [50], and fibrinolytic effect by inhibiting lipid peroxidation and hemolysis in oxidized erythrocytes [51]. It was also reported that onion and garlic had a blood pressure lowering effect by inducing intracellular nitric oxide and hydrogen sulfide production and inhibiting angiotensin-converting enzyme activity [52]. It was also shown that garlic reduced the levels of reactive oxygen species (ROS) that are thought to play a role in the pathogenesis of CVD and increased antioxidant capacity [52].

Although epidemiological studies investigating the relationship of onion consumption and CVD risk and CVD-related mortality rates are limited, a study conducted in Finland found that CVD-induced mortality was lower in individuals with high onion consumption than in those with low onion consumption [53]. Similar to garlic, onion also improves cardiovascular health through the sulfurous compounds, and especially flavonoids such as quercetin in its content. By cutting an onion, *S*-alk(en)yl-L-cysteine sulfoxides are converted into thiosulfinates and copaenes via the enzyme alliinase and these compounds inhibit platelet aggregation [54]. Since platelet aggregation is an important risk factor for the development of coronary thrombosis and atherosclerosis, onion consumption may be beneficial in individuals with risk factors for CVD. In addition, it was reported that onion consumption in hypercholesterolemic rats reduces CVD risk by decreasing the elevated inflammatory biomarkers associated with high cholesterol diet and by increasing the levels of antioxidant enzymes [55]. Onion also eliminates risk factors by correcting the dyslipidemia seen in some chronic diseases such as DM [9].

3.2.2. Leaf vegetables

Green leafy vegetables increase antioxidant capacity through minerals, vitamins, pulp, and phytochemical compounds in their content and protect against oxidative stress which is thought to play an important role in the pathogenesis of CVD [56]. In traditional diets where consumption of green leafy vegetables is high (Mediterranean and Japanese traditional diets), the rate of CVD is lower, and average life span is longer [57]. Moreover, in vegetarian individuals, mortality rates due to ischemic heart diseases and cerebrovascular diseases were also found to be lower than in non-vegetarians [58]. In another study, it was found that paralysis rates were significantly lower in individuals with higher consumption of green leafy vegetables than in individuals with less consumption of green leafy vegetables [59]. The incidence of coronary artery disease was also reported to be lower in individuals with higher green leafy vegetables consumption [53]. Individuals with more than three portions of green leafy vegetable consumption a day were found to have an ischemic heart disease incidence of about 60% less than those consuming less than 1 portion per day [60]. Furthermore, green leafy vegetables such as rocket, spinach, and lettuce also reduce blood pressure, inhibit platelet aggregation and improve endothelial dysfunction due to their rich inorganic nitrate content [57]. Some studies suggest that high nitrate content in the vegetables in this group is transformed into nitrite, nitric oxide, and vasodilator-tissue protective secondary compounds through symbiotic bacteria in the oral cavity, thereby maintaining cardiopulmonary function by lowering blood pressure [61].

3.2.3. Fruit and flower vegetables

The vegetables in this group are rich in sulfur-containing glucosinolates, flavonoids, anthocyanins, coumarins, carotenoids, antioxidant enzymes, and terpenes [62]. However, indole-3-carbinol and sulforaphane, which is a hydrolysis product of glucoraphanin, are thought to be the main bioactive compounds that are protective against CVD [63]. In experimental animals, sulforaphane protects against ischemic damage to the heart through induction of

Nrf2-related phase-II enzymes such as SOD, CAT, and hemoxygenase-1 [64]. Indole-3-carbinol and sulforaphane also protect against inflammation by inhibiting cytokine production [63]. In some epidemiological studies, it has been argued that consumption of vegetables in this group may reduce CVD-related mortality rates [65, 66]. It has been reported that anthocyanins extracted from red cabbage have protective effect on blood platelets [67], while broccoli sprouts decrease TC and LDL levels and increase HDL levels [68].

3.2.4. Legumes

The vegetables in this group are protective against CVD due to their high saponin and soluble fiber content. Another reason why legumes are beneficial for heart health is their low sodium and high potassium, calcium, and magnesium content [69]. The soluble pulp reduces the levels of TC and LDL by inhibiting the absorption of bile acid from the intestines and enabling the formation of short chain fatty acids, particularly propionic acid, that inhibit the synthesis of cholesterol [70]. It also improves heart health by inhibiting platelet aggregation [71]. In long-term observational epidemiologic studies, increased legume consumption has been reported to reduce CVD-related mortality and may protect against these diseases [69, 72, 73].

3.3. Effects on cancer

Cancer occurs as cells grow and proliferative without control [74]. Cancer occurs, progresses, and spreads as a result of abnormal signals in the body due to genetic or epigenetic effects [75]. Cancer is among the main causes of death in the world. On average, 16% of deaths occur each year due to cancer [76]. Lifestyle and many genetic and environmental factors can cause cancer. Smoking, consumed foods, solar radiation, and carcinogens in the environment are among these factors. The most important step in the treatment of cancer is the prevention of cancer. In particular, it is important to use health-related preventive practices in the communities and individuals at risk [75].

Consuming plant-based foods, especially increasing the consumption of vegetables, reduces the risk of cancer [74]. The antioxidants in vegetables help reduce the risk of cancer by preventing oxidative damage to the cells in the body [77]. Vegetables have protective effects against cancer due to the vitamins, minerals, pulp, and phytochemicals they contain [78]. About 14% of deaths worldwide due to inadequate vegetable consumption are caused by gastrointestinal cancers [79].

In a meta-analysis, the effects of vegetable consumption on cancer incidence were examined. Fruit and vegetable consumption were found to decrease cancer risk independently of each other and it was found that an extra portion of vegetables consumed daily resulted in a 3% reduction in cancer incidence [80].

A study investigating the relationship between vegetable and fruit consumption and epithelial ovarian cancer included 500 cancer patients and 500 control subjects. Cancer patients were found to have significantly lower average amounts of vegetables and fruits consumed per day than the control group [81]. However, in a cohort study investigating the relationship between vegetable and fruit consumption and pancreatic cancer, no significant relationship was found [82].

3.3.1. Root, bulb, and tuber vegetables

Vegetables in this group exert their protective effect against cancer through inositol, flavonoids, lignans, polyphenols, protease inhibitors, saponins, steroids, triterpenoids, isoflavones, phenolic acids, protein kinase inhibitors, sphingolipids, allicin, aline, and allyl sulfides [78].

Onions prevent tumor formation and cancer cells from spreading in many kinds of cancers such as stomach, ovary, breast, and colon cancer [83]. It has been shown that onion extract has apoptosis-inducing effects in MDA-MB-231 cells that cause breast cancer [84].

Compounds such as thyroallyl found in garlic are effective in preventing cancer. Such compounds in garlic have antioxidant effects that prevent and reduce carcinogens in DNA. They are also effective in reducing free radicals, inducing apoptosis, and stimulating the immune system [85, 86]. In a meta-analysis, the relationship between all cancer types and garlic consumption was investigated and it was concluded that garlic consumption was protective against gastric and intestinal cancers [87].

A controlled study investigating the relationship between onion and garlic consumption and gastric cancer included 759 cancer patients and 750 control subjects. As a result of the study, both onion and garlic consumption were found to have a negative relationship with cancer [88].

Carrot, which is a good source of flavonoids, polyacetylenes, vitamins and minerals, and carotenes, is also effective in protecting against cancer. Carrots have antioxidant, anticarcinogenic, and immune system enhancing properties [89]. In a study, it was determined that carrot consumption was negatively related to prostate cancer [90]. In another study conducted on rats, carrot consumption was shown to have protective effects against cancer due to the high content of carotenoids found in carrots [91].

3.3.2. Leaf vegetables

Green leafy vegetables reduce the risk of cancer due to phytochemicals, vitamin C, vitamin E, vitamin K, and vitamin A they contain [92]. The phytochemicals in these vegetables strengthen the immune system, protect against carcinogenic substances, reduce inflammation and oxidative stress that causes cancer, reduce DNA damage, prevent the growth of cancer cells, inhibit angiogenesis that is effective in tumor growth and regulate hormones [78, 93]. It is thought that these effects are exerted especially in cancer types such as breast, skin, lung, and stomach [78]. The main phytochemicals believed to be protective against these cancer types are isothiocyanates [92]. Apart from these phytochemicals, green leafy vegetables are protective against cancer, especially gastrointestinal system carcinomas, due to high pulp content [93].

In this group, spinach shows protective effects against cancer by reducing oxidative stress in the body thanks to vitamins A, C, and E, carotenes such as beta carotene and lutein, flavones and flavonoids it contains [94, 95].

Broccoli is another vegetable that is effective in protecting against cancer. A number of epidemiological studies have associated broccoli to low incidence of cancer. Sulfurous compounds found in broccoli are cancer preventive agents [96]. In addition to sulfurous compounds, there are carotenes and other antioxidant vitamins in broccoli. But the most effective compounds in preventing cancer are the sulfurous compounds in broccoli. These sulfurous compounds inhibit cancer formation by reducing free radicals and preventing cell damage [97].

3.3.3. Fruit and flower vegetables

Tomato, a good source of beta carotene and lycopene, reduces free radical damage in the DNA that causes cancer and prevents the growth and spread of cancer cells just like green leafy vegetables [78]. Lycopene is especially protective against prostate cancer [78, 98].

In an epidemiological study, consuming tomato and tomato products was found to be associated with a lower incidence of prostate cancer [99].

Results of a study investigating the relationship of tomatoes and tomato products with cancer revealed that the consumption of tomatoes and tomato products decreased cancer risk [98].

In another study, lycopene in tomatoes was shown to inhibit the growth and spread of cancer cells in lung cancer by reducing oxidative stress and inducing apoptosis [100].

Another vegetable in this group associated with cancer is pepper because of the capsaicin it contains. Capsaicin is thought to prevent cancer cells from growing, developing, and spreading [101].

4. Effect of preparing and cooking methods on vegetables

Vegetables are one of the most important components of human diet and are rich sources of β-carotene (provitamin A), thiamine (B1), riboflavin (B2), niacin (B3), pantothenic acid (B5), pyridoxine (B6), folic acid, ascorbic acid (vitamin C), vitamins E and K, minerals (such as iron, zinc, calcium, magnesium, and selenium), antioxidants (such as carotenoids, polyphenols, and glucosinolates), and fiber [102].

Preparation and cooking methods can greatly affect the nutritional content and acceptability of vegetables. There is no consensus in the literature as to what is the best way of preserving bioactive compounds while preparing and cooking vegetables [103].

Some vegetables are subjected to peeling in order to remove their shell or skin and make them more digestible. Minerals and other nutrients are affected by peeling. This can also cause severe loss of certain vitamins. It is known that peeling before boiling increases the loss of ascorbic acid, folic acid, or other vitamins of group B. Chopping vegetables can also change the bioavailability of bioactive compounds such as vitamins, carotenoids, polyphenols, and flavonoids [104].Thawing, cutting, and crashing citrus vegetables can also disrupt antioxidant glucosinolates due to the presence of myrosinase enzyme found in these vegetables [105].

Cooking improves the flavor of vegetables and enables the nutrients in the vegetables to be more easily used by the digestive system. However, cooking results in some physical and chemical changes in vegetables [106]. The effect of cooking procedure may vary depending on the various factors such as cooking technique, temperature, leakage into the cooking environment, solvent used for extraction, surface area exposed to water and oxygen, and pH [107]. In addition, each food matrix contains different compounds; therefore the same cooking technique may have different effects depending on the type of vegetable [108].

The most commonly used cooking methods are steaming, roasting, boiling, frying, sautéing, sous vide, microwave, and pressure cooking [109]. Cooking techniques affect polyphenol content and antioxidant activity levels in vegetables. Heat treatment can lead to a change in the chemical structures of vegetables, leading to the breakdown of cells and the degradation of some phenolic compounds from biological structures, the release of phenolics from the food matrix, and the conversion of insoluble phenolics to more soluble forms [110, 111]. In addition, the phenolic compounds are soluble in water. Thus, water-based cooking techniques often lead to loss of phenolics by leaking [103].

It has been reported that food processing has negative effects due to oxidation dependent losses in carotenoids and positive effects as it provides increased bioavailability [112]. Among the causes of increased carotenoid concentration in heat treatment may be greater extractability, enzymatic breakdowns, and incalculable moisture losses. Heat treatment also causes inactivation of enzymes and degradation of structures in the food matrix leading to increased bioavailability [113, 114].

The losses of minerals during preparation and cooking stages of vegetables are closely related to their solubility. Minerals are generally stable against a large number of conditions encountered during cooking, such as heat, oxidation, acidity or alkalinity. Potassium is an abundant mineral found in vegetables, and because of its high solubility in water, it is easily lost by leakage during cooking. Calcium and magnesium are usually present in an attached form in plant tissue and are therefore not easily lost by leakage. The loss of vitamin C is due in part to oxidative degradation during preparation and cooking and partly due to the leakage of the vitamin into the water used for cooking. The amount of vitamins degraded during cooking may be quite small compared to the amount lost due to leakage [115]. Due to its solubility and reactivity, folate is susceptible to potentially large losses during food processing and storage. The chemical stability of folates in plant-based foods may be adversely affected by heat, oxygen exposure, and light intensity. Since folate is highly soluble, its losses occur by leakage through the water used for washing, boiling, and cooking [116].

4.1. Root, bulb, and tuber vegetables

Onion is the richest source of quercetin, which is a flavonoid, and it is most widely used source in diet. Gennaro et al. found a 21% reduction in total quercetin uptake after onion peeling [117].

In another study on onions, the effects of boiling, microwaving, frying, and warm holding onion at 60°C for 1–2 hours on flavonoid amounts were investigated and peeling and boiling were found to decrease flavonoid levels in onion by up to 50%. It was found that other cooking methods and warming treatments did not have a significant effect on flavonoid amount [118].

Regarding the effects of cooking on onions, Lombard et al. found a 7% increase in flavonol concentration when sautéed, a 25% increase when oven baking, and an 18% decrease when boiled. They also stated that less than 5 minutes of cooking can result in retention of more than 80% of flavonols [119].

Potato contains various phenolic compounds, mainly chlorogenic acid and caffeic acid. There are several studies showing that cooking reduces [120], does not affect [121] or increases [122–125] phenolic compounds in potato. The reason for the increase in phenolic compounds during cooking is attributed to the increase in the extractability of these compounds from the cellular matrix of potato due to the textural changes in its starch structure during cooking [122].

Carrot is one of the important root vegetables rich in bioactive compounds such as carotenoids and dietary fiber. Bembem and Sadana investigated the effects of different cooking methods (boiling, steaming, pressure cooking, microwaving, and sautéing) on total phenolic content (TPC), total flavonoid content (TFC), total carotenoid and β-carotene content and antioxidant activity, and found that sautéing was the method that increased total carotene, β-carotene, and TPC the most. They reached the conclusion that sautéing and microwaving were the most appropriate ways of cooking carrots [126].

When the effect of boiling and steaming of frozen carrot on phenolic compound content was investigated, it was determined that phenolic content of carrot was significantly decreased at the end of the boiling process, whereas there was an increase in the steaming method [127]. The decrease during boiling may be due to the leakage of phenolic compounds into the boiling water.

4.2. Leaf vegetables

In a study investigating the effect of different cooking methods (boiling, steam cooking, and microwave cooking) on phytochemical content and total antioxidant capacity (TAC) of cabbage and black cabbage, which are part of the *Brassicaceae* family and are rich sources of vitamins and phytochemical compounds such as carotenoids and polyphenols, it was found that the best method in preserving the nutritious quality of vegetables was steam cooking. It was also shown that fresh vegetables preserved phytochemical compounds and TAC better than frozen samples [128].

Chang et al. studied the losses in nutritional value of several green leafy vegetables including Chinese cabbage (*Brassica pekinensis* var. *Cephalata*), swamp cabbage (*Ipomoea aquatica*), spinach (*Spinacia oleracea*), Ceylon spinach (*Basella rubra*), red spinach (*Amaranthus gangeticus*), white spinach (*Amaranthus viridis*), and Tapioca sprouts (*Manihot utilissima*) when they were treated with boiling or deep frying for 4 and 8 minutes, and found that frying reduced lutein content in all vegetables by 8–89%, and boiling reduced lutein content by 0–428%. When 8 minutes boiling procedure was compared with the 4 minutes procedure, β-carotene retention in vegetables other than Chinese cabbage and spinach changed between 18 and 380%, whereas in the frying procedure β-carotene retention increased by 2–3 times except spinach [129]. The difference in cooking conditions (time and temperature), the type of vegetables, and the interaction between cooking methods and vegetable type may be the cause of differences observed in carotenoid composition.

4.2.1. Fruit and flower vegetables

Alvi et al. investigated the effects of peeling on tomato, which contains vitamins A, C, and E, as well as various phytochemical compounds including lycopene, and found a reduction of 18.3% in fiber, 25.4% in calcium, 32.6% in magnesium, 6.4% in phosphor, 2.9% in potassium, 28.9% in ascorbic acid, and 17.2% in folic acid after peeling [130].

Dolinsky et al. found that the cooking method that maximized the polyphenol concentration and antioxidant capacity of tomatoes was steaming, and that microwaving significantly reduced the polyphenol content in tomatoes, and recommended microwave cooking less than other cooking methods (boiling, steaming, and pressure cooking) [131].

Pepper (*Capsicum annuum* L.) is considered to be an excellent source of antioxidants and is very rich in ascorbic acid and other phytochemicals. In a study conducted with six species of pepper, three different cooking methods were used (frying, boiling, and microwaving) and antioxidant properties of peppers after cooking procedures were evaluated. Reductions in radical scavenging activity (RSA) and total phenolic contents (TP) were observed after all cooking procedures, but the reductions after frying and microwaving were not statistically significant when compared to the initial RSA and TP levels. After a 5-minutes boiling, a 77% reduction compared to initial RSA levels was obtained, and when the boiling time increased to 30 minutes, the RSA totals decreased significantly compared to raw peppers. Significant reductions were also observed in TP after 5 and 30 minutes of boiling [132]. Based on these results, it can be said that the most suitable heat treatment method for peppers are microwave use and frying. If boiling is to be performed, shorter cooking time, less water usage, and consumption of cooking water can also reduce the amount of antioxidants that can be lost.

Artichoke, which is characterized by a complex antioxidant profile, contains many bioactive compounds such as glycosides and phenolic compounds, especially caffeicinic acid. Ferracane et al. applied boiling, frying, and steam cooking methods on artichoke and found an increase in overall caffeicinic acid concentration due to the formation of different dicaffeicinic acid isomers in cooked artichokes compared to raw ones. However, a higher increase in the concentration of dicaffeicinic acid was observed in steamed and fried artichokes compared to those boiled. In addition, flavonoid concentrations were reduced in all cooking processes and this reduction was largest in frying [133].

In a study comparing vitamin C content of raw, boiled, and microwaved broccoli and cauliflower, significant reductions in vitamin C contents were found after cooking processes. Boiling process caused more vitamin C loss compared to microwaving. After 6 minutes of boiling, vitamin C levels decreased by 64.5% in broccoli, by 70.7% in white cabbage, and by 66.8% in cauliflower [134]. Based on the results, it can be said that microwaving may be preferred instead of boiling to reduce vitamin C losses.

Yuan et al. investigated the effects of steaming, microwaving, boiling, frying, and boiling followed by frying processes on vitamin C levels in broccoli. At the end of the study, it was found that in all procedures except the steaming method, loss of vitamin C was significant compared to initial levels and the highest loss was obtained in boiling followed by frying (38%) and boiling (33%) [135].

When we look at other studies conducted with broccoli belonging to the *Brassicaceae* family, it is also seen that steaming is the best way to preserve nutritional quality of broccoli [107, 136–138].

It is known for a long time that loss of nutrients in vegetables occurs during the preparation and cooking stages. Knowing the conditions that cause these losses can help limit the losses and increase the nutritional quality of the foods.

5. Conclusion

Numerous preclinical studies carried out in recent years have identified beneficial protective and enhancing effects of vegetables on health, resulting from the nutritional and non-nutritional phytochemical contents of vegetables. These phytochemicals have the ability to modify the cellular function by modulating transcription factors and altering gene expression, cellular metabolism, and cellular signaling. The World Health Organization (WHO) recommends daily intake of 5–8 portions (400–600 g) of fruits and vegetables to reduce the risk of micro nutrient deficiency, cardiovascular diseases, cancer, cognitive impairment, and other nutritional health risks.

In order to make optimum use of the nutritional content of vegetables, choosing the right methods of preparation and cooking is as important as the consumption of adequate amounts of vegetables. To minimize nutritional losses, vegetables should be chopped right before cooking, if possible by hand or by metal tools while making the minimum contact possible, each vegetable should be cooked with the method and time that is most appropriate for that vegetable, and consumed as soon as possible.

Conflict of interest

There is no 'conflict of interest'.

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