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Review Article

Nutrition for Cancer Prevention and Control: A Review of Dietary Risk Factors and Protective Measures

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Abstract

Dietary management is one of the top research interests in the field of human cancer, but due to the heavy focus of cancer studies mainly on detection and medical treatment, the role of nutrition in prevention has generally received little research attention, and standards of care in cancer treatment do not effectively consider diet-based interventions as either an alternative or a complementary practice. It is generally believed that an unbalanced diet, unhealthy dietary patterns, and the consumption of nutrient-deficient foods contribute to the occurrence of various cancers. In contrast, adequate consumption of healthy, natural foods rich in essential nutrients may reduce the risk of cancer and help cancer patients better recover from the adverse effects of medical treatments. However, little is known about how dietary interventions interact with cancer. This study aims to provide an overview of several major dietary cancer risk factors and protective measures, as well as nutritional recommendations for the management of this disease. Moreover, based on the Warburg hypothesis, several potential dietary interventions have been identified to help maintain nutritional balance and reduce cancer risk. The findings of this study suggest that a balanced healthy diet with alkalizing and anti-inflammatory properties may be effective for maintaining certain aspects of health and reducing the risk of developing cancer. Further research should be performed to explore whether such dietary interventions could have an impact on the incidence or development of cancer.

Introduction

Cancer is a disease characterized by uncontrolled cell growth and the acquisition of metastatic properties. Research shows that only 5–10% of cancers may be directly attributed to genetic defects, and the rest are rooted in diet, environment and lifestyle. Although most cancers can be controlled by modifiable factors, cancer incidence rates are increasing globally, and an increase in cancer burden is predicted to be more significant in the future if current trends continue without effective global strategies for cancer prevention.[1,2]

Despite extensive research and significant investments in advanced medical treatments, cancer has been one of the leading causes of death worldwide in recent years, accounting for approximately 10 million annual deaths, including approximately 3 million cancer deaths in China and 600,000 cancer deaths in the USA.[3] Hence, cancer patients may need complementary therapies such as dietary interventions and lifestyle modifications to control cancer more effectively and increase survival rates.[4–6]

A growing number of observational studies have shown that a healthy, balanced diet can reduce the risk of cancer and improve the outcome of cancer treatment.[7–9] However, due to the predominant focus of cancer studies on detection and medical treatment, the role of nutrition in prevention and control has generally received limited research attention. Hence, the efficacy and safety of diet-based methods are uncertain, and standards of care in cancer treatment generally do not effectively take diet into account.[7,10,11]

This study aims to provide an overview of dietary cancer risk factors and diet-based health practices for more effective management of this disease.

Anti-inflammatory diet

Chronic inflammation is a significant cellular stress factor that leads to the exacerbation of metabolic disorders and the development of several non-communicable diseases, such as cancer.[12] A systematic review and meta-analysis on the association between dietary inflammatory index and the incidence of cancer has highlighted that pro-inflammatory diets are generally associated with an increased risk of cancer compared to anti-inflammatory diets, confirming that an inflammatory diet is a cancer risk factor.[13]

Keywords: Cancer; Healthy diet; Warburg effect; Balanced alkalizing diet; Anti-inflammatory diet.

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Chronic inflammation caused by the consumption of inflammatory foods, even at a low grade, may significantly increase the risk of cancer. Hence, as a dietary intervention for cancer, an anti-inflammatory diet can reduce the risk of cancer by limiting the intake of foods that are thought to cause chronic inflammation.[12,14]

It is commonly recommended to include anti-inflammatory foods such as tomatoes, olive oil, green leafy vegetables, fruits like oranges, and healthy nuts such as almonds regularly in the diet. In contrast, some foods, such as refined carbohydrates, alcohol, fried potatoes, soda, and red meat, are known to cause inflammation and should be avoided or limited as much as possible to reduce the risk of cancer, as well as to better manage the disease.[14]

Alkalizing diet

According to the Warburg hypothesis, one of the main causes of cancer is a lack of sufficient oxygen (hypoxia) at the cellular level, which leads to anaerobic cellular respiration and significant production of lactic acid (lactic acidosis, toxic to many cells), causing inflammation.[7,15,16] The risk of acidosis and other pH imbalances may be more significant in older people because they gradually lose some renal acid-base regulatory function, reducing the effectiveness of the buffering mechanisms in the body.[8]

A systematic review and meta-analysis on the association between acidosis and cancer risk has highlighted that a high acid load might be associated with an increased risk of cancer, as well as a poor prognosis.[17] In contrast, providing essential nutrients, and maintaining an optimal cellular pH and oxygen levels may inhibit cancer progression while preserving healthy cells.[8]

To improve acid-base disorders, a sufficient intake of foods that have an alkalizing effect at the cellular level may be effective at reducing the risk of cancer according to the Warburg hypothesis.[7,8] However, some researchers without valid scientific references have proposed consuming alkaline water, baking soda (sodium bicarbonate), or potassium bicarbonate supplements for cancer treatment, which have no significant effect on improving acid-base imbalances or reducing cancer risk, and their consumption may be associated with adverse effects.[8,18,19]

A healthy diet that includes certain raw foods with a negative dietary acid load (alkalizing at the cellular level, that is, not alkaline when consumed) may yield various health benefits, including increasing blood oxygen saturation at the cellular level, which reduces the risk of cancer.[12] Table 1 presents the relevant practical food chart.[7,8] To have a balanced diet according to the food chart, it is advisable to include sufficient amounts of foods with a negative dietary acid load (alkalizer) in meals that contain foods with a positive dietary acid load (acidifier).[7]

Metabolic balanced diet

A metabolically balanced diet is an eating plan designed to help the body's natural ability to regulate energy and fuel levels. Evidence shows that metabolic balance helps the body produce the required energy more effectively and more easily, leading to a balance between energy intake and energy expenditure that is fundamental to health and survival.[7] The energy imbalance may be a major concern for cancer patients due to unfavorable physiological, biological, and behavioral alterations during and following cancer treatment.[20] A systematic review of the literature on energy metabolism in patients who received chemotherapy suggested that these patients become hypometabolic during treatment, suppressing their metabolic rate and suspending normal activities.[21]

Diet type is a key factor that controls metabolic balance in the human body because the consumption of certain foods or drinks may increase metabolism or lead to a decrease in metabolic rate.[7] However, studies on the detailed food properties in terms of their effect on metabolism in the human body are limited. Table 2 presents a food chart based on Persian traditional medicine science that can be used as a guide to balance the diet for energy.[7] Further research is needed to explore whether these foods could have such an impact on the metabolic rate.

Hydrating diet

Dietary and drinking habits are key factors that control hydration in the body. Effective hydration by drinking clean, chemical-free water and sufficient consumption of fresh fruits and vegetables can help maintain the balance of body fluids, deliver nutrients to cells more effectively, maintain proper organ function, prevent degenerative disc disease, improve sleep quality, aid in detoxifying the body from carcinogens, and reduce the risk of cancer.[7,22] Particularly in cancer patients, the risk of dehydration is significantly higher due to the disease and its treatment according to the clinical and scientific literature.[23] Regularly drinking water from plastic bottles containing bisphenol A may increase the risk of developing certain cancers.[6]

Depending on their properties, certain foods and drinks may improve or decrease hydration. For instance, most fresh vegetables and fruits are made up of mostly water molecules, which help with body hydration.[24] In contrast, alcohol and caffeine are diuretics, meaning that they cause the body to expel a large amount of water as it tries to break down and eliminate the waste that they produce, leading to dehydration and electrolyte imbalances.[25,26] However, studies on the detailed hydrating properties of foods in the human body are limited. Table 3 presents a food chart based on Persian traditional medicine science that can be used as a guide for balancing the diet for hydration.[7] Further research should examine whether these foods could have such an impact.

Plant-based diets

Plant-based diets in general encompass a wide range of dietary patterns that involve low amounts of animal products and high amounts of plant products. In particular, some plant-based diets, such as vegetarian and vegan, exclude the consumption of some or all foods of animal origin.[27]

Studies on typical vegetarian diets in Western countries have not shown clear differences in cancer incidence between vegetarians and non-vegetarians, which suggests that a vegetarian diet may not necessarily reduce the risk of developing cancers.[27] These negative consequences may be due to the regular and high consumption of certain plant-based foods and beverages known to have adverse health effects. These include peanuts, flaxseeds, broccoli, ketchup, jams, frying oil, energy drinks, coffee, green tea extract, excessive green tea consumption, vegetarian chocolates, veggie burgers, fried potatoes, soy products such as tofu and soymilk, refined and ultra-processed foods, corn chips, breakfast cereal made from toasting flakes of corn, and foods with added extra bran or chopped grains instead of whole wheat flour.[7,28–32] Moreover, the overconsumption of pickled vegetables preserved in salt and vinegar (such as pickled cucumber) may increase the risk of developing cancers in the stomach and esophagus according to a systematic review and meta-analysis.[33]

In regard to dietary practices for cancer prevention, appropriate

Table 1. Food characteristics related to acidogenic or alkalizing effect for certain foods[8]

Category	Acidifier (Positive Dietary Acid Load)			Alkalizer (Negative Dietary Acid Load)		
	Strong (least healthy)	Medium	Weak	Weak	Medium	Strong (healthiest)
Fruits	Prunes, canned fruits, industrial juices	Sour cherry, sour plum	Sweet plums, unripe fruits	Oranges, bananas, cherries, peaches, pomegranates	Grapes, apples, pears, melons, raisins,	Lemons, dates, figs, mangoes
Vegetables, Beans, Legumes	Fried potatoes, chips, pickled vegetables	Lima beans, peas, lentils, boiled potatoes	Kidney beans, some cooked vegetables	Cucumbers, carrots, tomatoes, mushrooms cabbage, green peas	Olives, green beans, okra, turnips, celery, pumpkin, bell peppers	Garlic, onions, spinach
Nuts and Seeds	Peanuts, cashews	Walnuts, pistachios	Seeds of pumpkin, sunflower, sesame	–	–	Raw almonds
Meats	Pork, shellfish, rabbit	Beef, lamb turkey, veal	Fish, chicken	–	–	–
Eggs and Dairy	Cream, ice cream	Homogenized cow's milk, cheese, industrial eggs	Yogurt, raw milk, farm eggs	–	–	–
Grains and Cereals	Pastries, pasta, cereals	White rice, white flour, oats, bread	Whole wheat, brown rice	–	–	–
Oils	Frying oils	Sunflower oil, sesame oil	–	–	–	Virgin olive oil
Drinks	Liquor, beer, most soft drinks	Green tea, black Tea, coffee, wine	Bottled water	Spring mineral water, fresh ginger tea, fresh quince tea	Lemon juice, other fresh fruit juices, fresh vegetable juices	–
Other foods	Chocolate, ketchup, mayonnaise, protein shakes	Jam, sugar, vinegar	Processed honey	Ginger, natural honey	–	–

plant-based food choices should be considered. Numerous studies have demonstrated that the observed deficiencies and adverse health effects associated with plant-based diets are usually due to poor meal planning and a lack of clarity regarding the best or worst plant-based foods for cancer prevention. In fact, a well-balanced plant-based diet that sufficiently includes suitable food choices is suitable for all life stages and effective in fighting cancers.[7,34] A good example is the Hovannessian live, raw plant-based diet,

Table 2. Food characteristics related to the metabolic rate of certain foods[7]

Category	Increasing Metabolism (Warming nature)	Slowing Down Metabolism (Cooling nature)
Fruits	Grape, date, banana, melons, apples	Pomegranate, lemons, oranges, kiwis, watermelons, sour apples
Vegetables	Carrots, turnips, onions, garlic, peppers	Cucumbers, celery, tomato, lettuce, potato
Nuts and Seeds	Almonds, walnuts, sunflowers, sesame seeds	Flixweed
Meats	Sheep, camel, farm chickens	Fish, cow, goat
Eggs and Dairy	Yolk, farm butter from sheep	Egg white, Milk, Yogurt, Cheese
Grains, Beans, Legumes	Beans, green beans, peas, green peas, whole wheat	White rice, lentils
Oils	Olive oil, sesame oil, sunflower oil	–
Drinks	Ginger drink, ginger tea, cinnamon tea	Coffee, industrial lemon juice
Other foods	Ginger, black pepper, red pepper, cinnamon, turmeric	Terminalia Chebula (Black Halila)

Table 3. Food characteristics related to hydration for certain foods[7]

Category	Dehydrating (Drying nature)	Hydrating (Wetting nature)
Fruits	Sour cherries, sour plums, sour oranges	Cucumber, watermelon, sweet lemons, peaches, sweet oranges
Vegetables	Rhubarb	Carrots, zucchini, turnip, celery, tomatoes
Nuts and Seeds	Walnuts, sunflowers, sesame seeds	Almonds
Meats	Fried meats (particularly from cows and goats)	Lamb meat (cooked in boiling water)
Eggs and Dairy	Kashk, sour yogurt	Farm milk, farm yogurts
Grains, Beans, Legumes	White rice, lentils	Beans, green beans, peas, green peas, whole wheat
Drinks	Coffee, instant coffee, black tea, soft drinks, Beer, Wine	Water, ginger drink, vegetable juices, fruit juices
Other foods	Fried potatoes, chips, biscuits, cheese puffs, chocolate	–

which includes the necessary details about choosing the right foods and the correct way to prepare raw plant-based meals.[35] A systematic review and meta-analysis indicated that appropriate adherence to plant-based dietary patterns and healthy plant-based foods is beneficial for lowering the risks of major chronic diseases, including cancer.[36]

Adequate consumption of natural, unprocessed raw almonds, lemons, dates, mangoes, figs, grapes, garlic, red onions, green leafy vegetables, tomatoes, carrots, celery, cucumbers, sprouted wheat, sprouted peas, olive oil, spices and ginger, combined appropriately, can provide essential vitamins, minerals, enzymes, coenzymes, beneficial bacteria, and antioxidants with protective effects against cancer.[7,37] Additionally, a healthy vegetarian diet can also include certain boiled or steam-cooked plant-based foods, such as potatoes, carrots, whole rice, whole wheat, green peas, and green beans. It should be noted that consuming all vegetables in cooked form may have negative health effects, because some essential vitamins and key enzymes are heat sensitive and may be deactivated or damaged following exposure of foods to high temperatures during cooking.[38,39] As another good source of key nutrients, mushrooms can also be included in the diet.[40]

Evidence suggests that an appropriate plant-based diet with a balanced alkalizing effect may reduce the risk of breast cancer, prostate cancer, colorectal cancer, and lung cancer.[6,7,41,42] For instance, in a study on the effect of the dietary habits of African Americans, those who consumed fatty meat-heavy diets (a typical Western diet) had a significantly higher risk of colorectal cancer compared to those consuming rural African diets rich in beans and vegetables.[43]

Animal-based diets

An animal-based diet typically includes a high consumption of animal products such as meat, dairy, eggs, and seafood.[44] Animal foods are high in energy and generally contain protein, fat, certain minerals, and some vitamins, such as vitamin B_{12} and active vitamin D.[45,46] However, despite some benefits, excessive consumption of animal products may significantly increase the risk of cancer.[7] According to systematic reviews and meta-analyses, the consumption of red and processed meat is associated with an increased risk of various cancer types, such as breast, prostate, colorectal, and lung cancers.[36,47]

Milk plays an important role in the health of children, but a high intake of dairy products, such as cow's milk, low-fat milk, and cheese, is a risk factor for breast cancer in women[48] and significantly increases the risk of developing prostate cancer in men, according to systematic reviews and meta-analyses.[49–53] Hence, it makes sense for adults to be cautious about milk consumption.

The excessive consumption of red meats such as pork and beef may be associated with an increased risk of cancer due to being acidogenic and containing significant amounts of Neu5Gc (a cancer-causing sugar molecule).[7,54] Additionally, pigs and cattle have anatomy and genomes relatively similar to those of humans,[55–57] and the human immune system may sometimes not be able to discriminate the differences, attacking itself mistakenly following the consumption of products from such animals, particularly from pigs, leading to an increased risk of autoimmune diseases and related cancers.[58]

Some studies suggest moderate seafood consumption, such as fresh wild fish that is properly cooked (not fried), may lower the risk of cancer and other chronic diseases. However, excessive fish intake may increase the risk of specific cancers. In addition, regular consumption of fried fish, dried salted fish, farmed salmon, and tuna may increase the risk of cancer.[59–61]

Flexitarian diets

The flexitarian diet refers to individuals who want to have a plant-based diet without completely eliminating animal products from their diet. Such a flexible diet suggests high consumption of raw vegetables and plant-based proteins in daily meals, along with an appropriate selection of animal products in small to medium quantities, including fresh wild fish, eggs from farm chickens or quails, and meat from grass-fed lambs that regularly roam outside in the sun. In this case, a diet containing limited animal products that are properly cooked (not fried), should also contain a large amount of plant proteins and raw vegetables, as well as adequate amounts of herbs and spices such as black pepper, turmeric and ginger, to achieve nutritional balance and reduce the risk of cancer.[7,62]

Diabetes diet

A diabetes diet is an eating plan that helps control blood sugar.[63] Studies have shown that individuals who consume larger amounts of added sugar, especially sugar-sweetened beverages, tend to gain more weight and face an increased risk of cancer. This is because the amount of sugar used by cancer cells is approximately 10 to 15 times higher than normal cells, meaning that a high blood sugar level, particularly in the hypoxic regions of the body, may be favorable for cancer cells.[7,64]

While added sugars, artificial sweeteners and other unhealthy sources of sugars are unhealthy, some people think that the consumption of fruits may also increase the risk of cancer due to their sugar content. However, the truth about fruits is that the consumption of natural whole fruits such as almonds, lemons, apples, mangoes, dates and oranges is very beneficial for human health, especially when the fruits are sun-ripened on the tree, as they contain natural sugars that are a preferred energy source for human cells. Fruits contain various essential nutrients, such as vitamins, minerals, fiber, antioxidants, and phytochemicals, with protective effects against cancer. Additionally, some fruits, such as oranges, contain mannose, an anticancer sugar that interferes with glucose metabolism in tumor cells. Fruit consumption is recommended as a key part of a healthy diet for humans, and adequate consumption of fruits as a dietary habit should not be restricted even in individuals with diabetes.[7,65]

Several researchers have suggested a sugar-free, high-fat diet with moderate consumption of animal proteins (a ketogenic diet) for managing type 2 diabetes and controlling cancer. However, the ketogenic diet largely failed to treat cancers as a monotherapy, as cancer cells can eventually adapt to use fats for energy. Ketogenic diets are high in red meat, processed meat, and saturated fat, which increase cancer risk, but low in vegetables, fruits, fiber, legumes, and whole grains, which protect against cancer. Removing beneficial sugars from the diet to starve cancer cells could starve and weaken healthy cells as well, possibly accelerating cancer progression in some cases, with no benefits in terms of treatment outcomes and survival rates. Hence, sugar-free high-fat diets such as ketogenic diet are not recommended for either cancer prevention or cancer treatment, due to the associated risks for cancer patients.[7,66–70]

Nutrient-rich diets

Eating a well-planned nutrient-rich diet (but not eating too much food) is essential for overall health and reducing the risk of cancer.[7,71] Key protective elements in a cancer prevention diet include protein, omega-3 fatty acids, dietary fiber, vitamin C, vitamin D, vitamin E, vitamin B_6, vitamin B_9, vitamin B_{12}, calcium, magnesium, iron, potassium, and antioxidants.[7,72,73] The best sources of nutrients recommended for cancer prevention include fruits, vegetables, nuts, seeds, and legumes.[7]

Protein, an important part of a healthy diet, helps build and maintain muscles. Protein can be obtained from both plants and animals; however, high consumption of animal proteins is associated with an increased risk of cancer. Hence, dietary intervention aimed at reducing the consumption of animal proteins and increasing the intake of healthy plant proteins such as green beans, green peas, legumes, and nuts can be beneficial and effective in preventing and controlling cancers.[7,74,75] Furthermore, limiting animal protein consumption helps maintain safe, low levels of methionine, a sulfur-containing amino acid that is a precursor to some potentially toxic compounds that some cancer cells depend on for growth. Hence, limiting dietary methionine intake by reducing the consumption of animal proteins can reduce cancer risk.[40]

Omega-3 fatty acids play crucial roles in lipid and cell metabolism, membrane structure, cell signaling, gene expression and inflammation in the body and have anti-tumorigenic effects that help prevent and treat cancers.[76] Top rich and safe sources of omega-3 fatty acids include seafood, walnuts and olive oil.[40]

Sufficient dietary fiber intake has been associated with a reduced risk of several types of cancer, particularly colorectal cancer.[77] Moreover, breakdown of dietary fiber by beneficial gut bacteria generates significant amounts of butyric acid, which has cancer-inhibiting effects.[78] Hence, eating a variety of foods containing high fiber, such as raw vegetables, fruits, whole grains, legumes, and nuts, is recommended for cancer prevention and control.[7]

Vitamin C plays an important role in preventing cancer and can also attack various processes through which cancer cells grow and develop.[73] Normally, natural food sources such as fruits and vegetables can provide sufficient levels of vitamin C in the human body. Top sources of vitamin C include lemons, oranges, and apples as well as fresh red bell peppers, turnips, and parsley.[40]

Vitamin D is a fat-soluble vitamin that controls several biological activities that slow or prevent the development of cancer.[79] The National Academy of Medicine considers a serum 25(OH)D concentration in the range of 20–50 ng/ml to be sufficient (ideal), 12–20 ng/ml to be insufficient (moderate), and less than 12 ng/ml to be deficient.[40,80] Vitamin D deficiency (less than 12 ng/ml) may be linked to an increased risk of developing metabolic illnesses such as cancer. Most health professionals recommend receiving at least 10–30 minutes of sun exposure daily and/or consuming foods rich in active vitamin D. Those living at low latitudes, such as in the Middle East, North Africa and South Asia, may meet their requirements through sun exposure on clear sunny days of the year (maintaining a vitamin D level of at least 12 ng/ml). However, at high latitudes (such as in Scandinavian countries and Canada), very little vitamin D can be produced by the skin for at least six months of the year.[6] Dietary sources of vitamin D include D_3 in farm-raised eggs, farm-raised lamb, seafood, and some other animal products, as well as D_2 in mushrooms.[40] Farm animals raised at low latitudes and sufficiently roamed outdoors in the sun are a richer source of active vitamin D compared to animals raised at high latitudes, especially in factory farms where exposure of animals to sunlight is very limited. Mushrooms can also contain vitamin D, but only after sufficient exposure to direct ultraviolet sunlight on a clear day. Hence, commercial mushrooms may lack vitamin D unless they are adequately exposed to sunlight before consumption.[6,40]

Vitamin E is a group of fat-soluble antioxidant nutrients that consist of tocopherols and tocotrienols. Tocopherol, a major isoform of vitamin E, has been found to eliminate reactive oxygen species and inhibit carcinogenesis and tumor growth.[81] The natural sources of vitamin E include nuts (such as raw almonds), seeds (particularly sunflower seeds), fruits (such as mangoes), and vegetables (such as turnips).[40]

Vitamin B_6 has a significant impact on the risk of cancer, and sufficient intake of dietary (food only) vitamin B_6 may be significantly associated with decreased risk of all cancers.[82] Top sources of vitamin B_6 include carrots, spinach, bananas, green peas, chickpeas, and avocado.[40]

Vitamin B_9 (folate) in unhealthy amounts is significantly associated with cancer. Both folate deficiency and excessive folate intake may increase the risk of developing some cancers.[83] Folate deficiency has multiple causes, including poor dietary intake, alcoholism, and weakened stomach acid, such as due to routine consumption of antacids that affect folate absorption. Top sources of folate are beans; nuts, such as raw almonds, green leafy vegetables, such as spinach; and citrus fruits, such as lemons and oranges. For most people, it is relatively easy to obtain enough folic acid through a healthy balanced diet.[40]

Vitamin B_{12} plays a key role in DNA stability and can affect pathways that promote the proliferation of cancer cells. Research indicates that both inadequate and excessive intake of vitamin B_{12} may contribute to cancer development.[84] Vitamin B_{12} is not produced by cells in humans, animals or plants but by certain types of

bacteria in the healthy gut. Subsequently, it is absorbed and stored in body tissues. Grass-fed animal products such as those from farm lamb may be a rich source of vitamin B_{12} for humans, considering that the absorption of this vitamin is reduced by the consumption of antacids and excessive use of antibiotics.[40] In addition, a diet rich in appropriate, raw plant-based foods may improve the gut microbiome and help with the production of vitamin B_{12} by beneficial bacteria in the human gut.[40] Several studies have shown that vitamin B_{12} deficiency is relatively uncommon among native Indians consuming traditional farming products, probably due to their healthy gut microbiome. However, this deficiency has been found with significant frequency among vegetarian Indian immigrants in England.[85] Similarly, studies on Iranian villagers with traditional plant-based diets very low in animal products have indicated normal vitamin B_{12} levels.[86] This suggests that vitamin B_{12} deficiency can be prevented by maintaining a healthy gut microbiome, including in vegans.[40]

Calcium controls a wide variety of cellular processes, such as cell proliferation, death and migration.[87] The richest and healthiest plant-based sources of calcium include raw almonds, leafy green vegetables, figs, white beans, sesame seeds/paste, and okra.[88]

Magnesium is an essential micronutrient implicated in a large array of regulatory, metabolic and structural activities. Magnesium deficiency may be linked to an increased risk of some cancers.[89] Top sources of magnesium are dates, raw almonds, whole rice, fresh green vegetables such as spinach, and seeds such as pumpkin, sesame and sunflowers.[40]

Potassium is an essential macro-mineral required by the body to maintain cellular homeostasis, metabolism and many other functions playing a vital role in the maintenance of normal cell functions.[90] Many cancer patients experience major electrolyte imbalances, including extremely low levels of potassium in the blood (hypokalemia), which can be life-threatening.[91] Top rich and healthy sources of potassium include lemon, banana, carrot, orange, baked potato, and spinach.[92]

Iron is a necessary nutrient for humans which serves as a key component of oxygen transporters in the body and is also required for energy generation.[93] Plenty of evidence has shown that iron metabolism is closely related to the occurrence and development of tumors.[94] Some of the best foods rich in iron include dates, pistachios, whole grains, red grapes, pomegranates, spinach, pumpkin seeds and red kidney beans. These food sources of iron also naturally contain vitamin C, which promotes iron absorption. Furthermore, adding vitamin C-rich sources such as fresh lemon juice to our meals can help improve iron absorption from foods, as can avoiding coffee and black tea at meal times.[40]

Supplemented diet

Some researchers have claimed that supplements and products containing dietary ingredients, can provide all necessary vitamins and minerals for cancer prevention. Unfortunately, vitamins and minerals that are isolated into a supplement may not be absorbed as well as natural ones in whole foods and do not offer the same benefits.[95] Research suggests that vitamin/mineral supplements do not reduce the risk of cancer, and their use for cancer prevention is not recommended for cancer survivors worried about recurrence.[7,95] A systematic review and meta-analysis found no solid evidence for the use of minerals, vitamins, proteins, or other supplements in cancer.[96]

High doses of artificial supplements may have some adverse effects and even be harmful.[7,95] For example, vitamin D supplements do not reduce cancer mortality but may increase the risk of calcification, kidney damage, and prostate cancer.[7,97,98] High-dose omega-3 or vitamin-E supplements may increase the risk of aggressive prostate cancer.[99,100] Calcium supplements have been linked to an increased risk of death from cancer.[101] High-dose vitamin C supplements (1,000 mg or more) increase the risk of kidney stones.[102] High-dose beta-carotene supplements may increase the risk of lung cancer.[103] Excessive body iron levels, which can result from excessive consumption of high-dose iron supplements, may lead to an increased risk of colorectal cancer.[104] Folic acid supplementations may promote the progression of established precancerous lesions.[105] Too high intake of iodine obtained from supplementation or fortification, as well as iodine deficiency due to poor nutrition, are associated with an increased risk of certain cancers.[106] High-dose vitamin B_{12} supplements may increase the risk of colon cancer.[107] Overall, studies show no anti-carcinogenic value in vitamin/mineral supplements in an amount greater than that provided just by a well-balanced healthy diet.[7,108]

Some researchers have proposed consuming high concentrations of certain so-called anti-cancer substances in the form of supplements, but there is no solid evidence of their effectiveness and safety.[7] For instance, some foods, such as naturally grown raw almonds contain Amygdalin and release hydrogen cyanide upon hydrolysis. In low doses, this natural form obtained from small amounts of food in the diet may exhibit potential anticancer effects and can be detoxified by the body.[7,109,110] However, studies have shown that high-dose amygdalin sources in the form of supplements (sometimes commercially called Vitamin B_{17} supplements) are ineffective in treating cancers and may also cause cyanide poisoning.[7,111]

Reducing food contaminants

Certain food contaminants are known to increase the risk of cancer. Particularly where agricultural soil or groundwater is contaminated, food products may contain carcinogenic content, including toxic heavy metals such as cadmium, lead, arsenic, and fluoride. Furthermore, food products that have significant nitrate accumulation due to the excessive use of chemical fertilizers, as well as foods contaminated with the herbicide glyphosate, which is widely used in growing genetically modified crops, such as corn and soybeans, are linked to cancer.[7]

Some people try to eat foods that are labeled ‘organic’ (different from traditional farming products with no labels) to reduce the risk of cancer associated with carcinogens in foods. However, according to a large prospective study, ‘organic’ labeled products have shown little, if any, help in the prevention of various types of cancers.[112] An ‘organic’ label often does not refer to a non-toxic, nutrient-rich, or healthy product. In many cases, some industrial methods may still be utilized that are not prohibited in the organic definition standard, as well as some pesticides may be used, albeit natural ones, which can nevertheless be harmful to human health. In addition, standards for ‘organic’ certification, particularly in measuring and reporting the concentration of heavy or toxic elements in foods may vary by country and are often non-existent. The ‘organic-labeled’ fruits may also, in many cases, undergo artificial ripening processes rather than ripening naturally, which may not be as healthy as on-tree sun-ripened fruits.[7,8,113]

The stored toxic content in certain foods, such as potatoes, green beans, wheat, rice, carrots, celery, lettuce, and green leafy vegetables, may be reduced by thorough cleaning and washing. Subsequently, soaking them sufficiently in clean water and discarding the water, followed by replacement with fresh water for a few cycles

before cooking or consumption, can further help reduce toxic elements.[7] For example, soaking rice overnight before cooking can significantly reduce arsenic levels.[114] It should be noted that the optimal soaking time may vary depending on the type of vegetable, and prolonged soaking may spoil some vegetables.[7]

Conclusions

Unhealthy eating habits, including animal-based diets or inappropriate plant foods, may increase the risk of developing cancer. Therefore, cancer prevention requires a well-balanced, plant-based diet with appropriate food choices.

A sufficient intake of certain plant-based foods with anti-inflammatory and alkalizing effects in the human body can provide acid-base balance, an optimum metabolic rate, and sufficient hydration, which, along with a healthy lifestyle, may effectively reduce the risk of cancer.

Excessive consumption of animal foods, especially processed red meat and commercial dairy products, maybe a major risk factor for some cancers.

A high intake of acidogenic foods, such as animal proteins, peanuts, coffee, sugary drinks, alcoholic beverages and ultra-processed foods, may increase the risk of cancer, particularly in the hypoxic regions of the body according to the Warburg hypothesis.

The regular consumption of alkalizing foods such as raw almonds, dates, olives, and citrus fruits as a dietary habit (but not alkaline water or baking soda) may improve acid-base disorders and reduce the risk of developing cancers.

The overconsumption of pickled vegetables preserved in salt and vinegar (such as pickled cucumber) may increase the risk of developing cancers in the stomach and esophagus.

As this study was a review and limited in scope, more detailed studies are required to establish certain and proven guidelines for proposing a well-planned and balanced healthy diet for cancer patients.

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Conflict of interest

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