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A Review on Phytochemicals and their activities

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Abstract

Antioxidants are phytochemicals, vitamins and other nutrients that protect our cells from damage caused by free radicals. In vitro and in vivo studies have shown that antioxidants help prevent the free radical damage that is associated with cancer and heart disease. Antioxidants can be found in most fruits and vegetables but also culinary herbs and medicinal herbs can contain high levels of antioxidants. Carotenoids, tocopherols, ascorbates, lipoic acids and polyphenols are strong natural antioxidants with free radical scavenging activity. Endogenous antioxidants enzymes like super oxide dismutase (SOD), catalase, glutathione peroxidase, glutathione reductase, minerals like Se, Mn, Cu, Zn, vitamins A, C and E. Phytochemicals are non-nutritive plant chemicals that have protective or disease preventive properties. They play a crucial role in maintaining optimal immune response, such that deficient or excessive intakes can have negative impact on health. Dietary intake of phytochemicals may promote health benefits, protecting against chronic degenerative disorders, such as cancer, cardiovascular and neurodegenerative diseases. protection against numerous diseases or disorders such as cancers, coronary heart disease, diabetes, high blood pressure, inflammation, microbial, viral and parasitic infections, psychotic diseases, spasmodic conditions, ulcers, osteoporosis and associated disorders. They are non-essential nutrients, meaning that they are not required by the human body for sustaining life. It is well-known that plant produce these chemicals to protect themselves but recent research demonstrate that they can also protect humans against diseases. There are more than thousand known phytochemicals. Some of the well-known phytochemicals are lycopene in tomatoes, isoflavones in soy.

Keywords: Antioxidants, enzymes, plants, Diabetes, lycopene.

Introduction

Free radicals are formed as part of our natural metabolism but also by environmental factors, including smoking, pesticides, pollution and radiation. Free radicals are unstable molecules which react easily with essential molecules of our body, including DNA, fat and proteins. All organic and inorganic materials consist of atoms, which can be bound together to form molecules. Each atom has a specific number of protons (positively charged) and electrons (negatively charged). Most single atoms are not stable because they have to few or to may electrons. Atoms try to reach a state of maximum stability by giving away or receiving electrons from other atoms, thereby forming molecules. Free radicals are molecules which have one electron too much or too less in order to be stable. Free radicals try to steal or give electrons to other molecules, thereby changing their chemical structure. When a free radical attacks a molecule, it will then

become a free radical itself, causing a chain reaction which can result in the destruction of a cell. Antioxidants have the property to neutralize free radicals without becoming free radicals themselves. When antioxidants neutralize free radicals by receiving or donating an electron they do not become antioxidants themselves because they are stable in both forms. In other words, antioxidants are chemicals that offer up their own electrons to the free radicals, thus preventing cellular damage. However, when the antioxidant neutralizes a free radical it becomes inactive. Therefore we need to continuously supply our body with antioxidants. The action of free radicals could increase the risk of diseases such as cancer and heart problems and could accelerate ageing. Antioxidants have the property to neutralize the free radicals and prevent damage. Well known examples of antioxidants are the vitamin C, E and beta-carotene. These three vitamins are often added to the so called ACE drinks. But there are numerous other rather unknown antioxidants such as lycopene, lutein,

How do phytochemicals work

There are many phytochemicals and each works differently. The term phytochemicals, also known as phytonutrients, are naturally occurring substances found in plants. They help to protect the plant from the sun's ultraviolet rays, disease and fungus. They basically form the plant's immune system. This naturally occurring substance is what gives fruits, vegetables and herbs their colours. These same substances have been found to be beneficial for human health as well, as they have antioxidant activity.

These are some possible actions:

- **Antioxidant -** Most phytochemicals have antioxidant activity and protect our cells against oxidative damage and reduce the risk of developing certain types of cancer. Phytochemicals with antioxidant activity: allyl sulfides (onions, leeks, garlic), carotenoids (fruits, carrots), flavonoids (fruits, vegetables), polyphenols (tea, grapes).
- **Hormonal action** - Isoflavones, found in soy, imitate human estrogens and help to reduce menopausal symptoms and osteoporosis.
- **Stimulation of enzymes -** Indoles, which are found in cabbages, stimulate enzymes that make the estrogen less effective and could reduce the risk for breast cancer. Other phytochemicals, which interfere with enzymes, are protease inhibitors (soy and beans), terpenes (citrus fruits and cherries).
- **Interference with DNA replication -** Saponins found in beans interfere with the replication of cell DNA, thereby preventing the multiplication of cancer cells. Capsaicin, found in hot peppers, protects DNA from carcinogens.
- **Anti-bacterial effect -** The phytochemical allicin from garlic has anti-bacterial properties.
- **Physical action -** Some phytochemicals bind physically to cell walls thereby preventing the adhesion of pathogens to human cell walls. Proanthocyanidins are responsible for the anti-adhesion properties of cranberry. Consumption of cranberries will reduce the risk of urinary tract infections and will improve dental health.

How do we get enough phytochemicals?

Foods containing phytochemicals are already part of our daily diet. In fact, most foods contain phytochemicals except for some refined foods such as sugar or alcohol. Some foods, such as whole grains, vegetables, beans, fruits and herbs, contain many phytochemicals. The easiest way to get more phytochemicals is to eat more fruit (blueberries, cranberries, cherries, apple,...) and vegetables (cauliflower, cabbage, carrots, broccoli,...). It is recommended take daily at least 5 to 9 servings of fruits or vegetable. Fruits and vegetables are also rich in minerals, vitamins and fibre and low in saturated fat.

Future of phytochemicals

Phytochemicals are naturally present in many foods but it is expected that through bioengineering new plants will be developed, which will contain higher levels. This would make it easier to incorporate enough phytochemicals with our food.

Benefits of antioxidants

Numerous studies with plant phytochemicals show that phytochemicals with antioxidant activity may reduce risk of cancer and improve heart health.

Antioxidants reduce the risk of cancer

Not all results are conclusive but many studies show that antioxidants may reduce the risk of cancer. A study showed that a combination of the antioxidants beta-carotene, vitamin E and selenium significantly reduced incidence of cancer. However, the Alpha-Tocopherol / Beta-Carotene Cancer Prevention Study (1994) showed that intake of beta-carotene increased lung cancer rates of male smokers.

Antioxidants protect the heart

Everyone knows that cholesterol causes heart diseases and tries to limit cholesterol intake. But a more important cause of fatty buildups in the arteries is the oxidation of low-density lipoprotein cholesterol. The use of dietary supplements of antioxidants could reduce the risk of cardiovascular disease, but there is no hard evidence. At this stage, studies only show that the intake of foods, naturally rich in antioxidants reduces this risk.

Carotenoids, limonoids and polyphenols exert synergistic actions in scavenging free radicals. Synthetic antioxidants such as butylated hydroxy anisole (BHA) and butylated hydroxy toulene (BHT) play a useful role in food and pharmaceutical industries. The natural antioxidant system is mainly classified into two categories namely in-vitro and in-vivo antioxidants. Free radical scavengers act as hydrogen donors, electron donor, peroxide decomposer, singlet oxygen quencher, enzyme inhibitor, synergist, and metalchelating agents. Both enzymatic and non-enzymatic antioxidants exist in the intracellular and extra cellular environment to detoxify ROS. To provide maximum intracellular protection, these scavengers are strategically compartmentalized in the cell and offer protection that can be classified as follows:

A. First Line of Defense It comprises preventing antioxidants that act by quenching of O_2 - , decomposition of H_2O_2 and chelation of metal-ions and enzymes such as superoxide dismutase (SOD), catalase, glutathione peroxidase and non enzymatic molecules.

B. Second Line of Defense The antioxidants belonging to this category of defense include glutathione (GSH), mainly ascorbic acid, alphatocopherol (Vitamin C & E), carotenoids and flavonoides.

C. Third Line of Defense Third line antioxidants are complex group of enzymes for repairing damaged DNA, damaged proteins, oxidized lipids and also stop chain propagation of peroxyl lipid radicals.

D. Fourth Line of Defense A fourth line is related immune system and comes in operation when all other protections fail.

Phytochemicals and their health benefits

A. Polyphenols

Types of phytochemicals

There are many types of phytochemicals, some of the best known ones are, carotenoids, flavonoids and sulphur compounds.

Carotenoids

Carotenoids are a group of yellow, orange, red and green plant pigments with powerful antioxidant activity. Green leafy vegetables are also high in carotenoids.

These antioxidants are fat-soluble, meaning that they cannot easily be absorbed unless there is some fat (good fats) in the diet. The best known carotenoids are alpha-carotene, beta-carotene, lycopene, cryptoxanthin, lutein and zeaxanthin.

Research suggests that carotenoids offer many health benefits, such as reducing the risk of heart disease and certain types of cancer. They may also help with enhancing the immune system and protecting the body from eye, skin, liver and lung damage.

Flavonoids

Flavonoids are a large group of water-soluble antioxidants and some of which have red, blue and purple pigments.

Studies have shown that some flavonoids have a lot more antioxidant activity than vitamins C and E. The main subclasses include catechins, flavonols, flavanones, flavones and isoflavones.

These flavonoids have anti-cancer properties and help to keep blood vessels healthy.

Out of all the phytochemicals in fruits and vegetables, it's the flavonoids that we eat in the largest quantity in our diet each day.

Isoflavones are found in soybeans and other legumes. In the body they are converted into phytoestrogens (plant estrogens). Studies have shown that these hormone like compounds may help to inhibit the growth of cancer cells. They also help to provide protection against heart disease by helping to lower cholesterol levels.

Isoflavones can be beneficial for women's health and possibly help to reduce some of the symptoms of menopause that women suffer from, especially in western society.

Sulphur compounds

The groups of sulphur compounds are the allium and brassicas vegetables. Allium vegetables include garlic, leeks, onions and shallots. These vegetables also contain flavonoids, vitamin C and selenium. They have been shown to have cancer fighting properties and also be beneficial to cardiovascular health. Brassica vegetables include bok choi (Chinese cabbage) broccoli, brussels sprouts, cabbage, cauliflower, kale and watercress. These groups of vegetables also contain flavonoids and vitamin C. They have been found to help protect against many forms of cancer.Sulphur compounds are also found in grains, wheat germ, oatmeal and in fruits like figs, plantain, papaya and pineapple.

The colour of fruits and vegetables can give you a guide to the phytochemical content. The more colourful a fruit or vegetable is, the higher its phytochemical content, especially if they are coloured all the way through (like berries) not just on the skin (like apples).

With green leafy vegetables, the darker the better. For example, spinach is better than iceberg lettuce.

Below are the different coloured groups of fruits and vegetables.

Red

This group includes tomatoes (raw and cooked), red peppers, watermelon and pink grapefruit.

These contain lycopene which is part of the carotenoids group of phytochemicals. Lycopene has been found to help protect against prostate and other forms of cancer. It is interesting to know that lycopene is more available from cooked tomato products like pasta sauces and tomato soup and also from tomato juice, than from raw tomatoes.

Red/Purple

This group includes beets, blackberries, blueberries, cherries, cranberries, cranberry juice, eggplant, grapes, grape juice, plums, prunes, red apple, red cabbage, red wine and strawberries. These fruits and vegetables contain anthocyanins which is part of the flavonoids group of phytochemicals. These powerful phytochemicals are said to be beneficial to cardiovascular health.

Orange/Yellow

This group includes apricots, carrots (raw and cooked), mangos, nectarine, orange, papaya, peach, pineapple, pumpkin, rockmelon (cantaloupe), sweet potato, squash, tangerine and yellow grapefruit. These contain alpha and beta-carotenes which are part of the carotenoids group

of phytochemicals. These powerful phytochemicals may help to protect against certain cancers, heart disease and may help to enhance the immune system.

Yellow/Green

This group includes avocado, collard greens, corn, cucumber, green beans, green peas, green peppers, honeydew melon, kiwifruit, mustard greens, lettuce, spinach, turnip greens, yellow peppers and zucchini.These foods contain lutein and zeaxanthin. These have been identified as the most effective carotenoids for eye health. They are associated with lower incidences of cataracts and macular degeneration.

Green

This group includes bok choi (Chinese cabbage), broccoli, brussels sprouts, cabbage, cauliflower, kale, swiss chard and watercress. These contain sulphur compounds which have been shown to have cancer fighting properties.

White/Green

This group includes artichokes, asparagus, celery, chives, endive, garlic, leeks, mushrooms, onions, shallots and white wine. This group also contains sulphur compounds and are a good source of flavonoids.

List of phytochemicals

Alkaloids:- Theobromine Theophyline,Caffeine,

Monoterpenes :-Geranoids,Limonene

Organosufides:-Isothiocyanates,Glutathione,Allicin,Indole-3-carbinol.

Phenolic Acids:-Capsaicin,Ellagic acid,Gallic acid,Tannic acid.

Phytosterol,Anthrocyanins,Beta-Sitosterol,Phytic acid

Carotenoids:-
Beta-carotene,Lycopene,Lutein

Phytochemicals in Foods and Possible Health Benefits

Foods	Phytochemicals	Possible Health Benefits
Soybeans, soy milk, tofu	Isoflavones (genistin, daidzein), types of flavonoids	Reduction in blood pressure and increased blood vessel dilation
Strawberries, red wine, blueberries	Anthocyanins, a type of flavonoid	Blood vessel dilation, induction of cancer cell death, improved insulin sensitivity, neuroprotective effects
Red wine, grape juice, grape extracts, cocoa, peanuts	Proanthocyanidins, a type of flavonoid; resveratrol	Inhibition of LDL oxidation and inflammation
Garlic, onions, leeks, olives, scallions	Sulfides, thiols	Decreased LDL cholesterol, anticancer effects

Carrots, tomatoes and tomato products, other orange, yellow, and red fruits and vegetables	Carotenoids, such as lycopene, and beta-carotene	Neutralization of free radicals that cause cell damage
Cruciferous vegetables such as broccoli and kale, horseradish	Isothiocyanates (sulforaphane)	Neutralization of free radicals that cause cell damage and protection against some types of cancer
Green and black tea, cocoa	Catechins, epicatechins, types of flavonoids	Vasodilation, improved blood flow to the brain, improved insulin sensitivity

Discussion

Epidemiological studies provide convincing evidence that diet rich in antioxidants is associated with a lower incidence of degenerative diseases. The major sources of dietary polyphenols are cereals, legumes (barley, corn, nuts, oats, rice, sorghum, wheat, beans, and pulses), oilseeds (rapeseed, canola, flaxseed and olive seeds), fruits, vegetables and beverages (fruit juices, tea, coffee, cocoa, beer and wine). Fruits such as apple, grape, pear, cherry and various berries are rich sources of polyphenols. Red wine or a cup of coffee or tea contains about 100 mg polyphenols. Their total dietary intake may be about 1g per day, which is about 10 times higher than that of vitamin C and 100 times higher than those of vitamin E and carotenoids. The chief constituent of tea polyphenols are flavonols (catechin, epicatechin, catechingallate and epigallo-catechingallate), flavanols (quercetin, kaempferol and their glycosides), flavones (vitexin, isovintexin) and phenolic acids (gallic acid, chlorogenic acid). They constitute up to 30% of the dry weight of green leaves and 9-10% of the dry weight of black tea leaves. Ferulic acid is associated with dietary fiber linked with hemi cellulose of the cell wall by means of ester bonds. Caffeic acid in the form of caffeoyl esters and coumaric acids are common in apples, pears, and grapes. Additionally, apples and pears are rich in chlorogenic acid and grapes in gallic acid. Apples contain high levels of quercetin among fruits. Grain-derived products are especially significant in human diet as they have higher concentration of phenolic acids in the outer layers of kernel that constitute the bran. Most of the phenolic acid derivatives are hydrolysable tannins and are usually esterified with glucose. Citrus fruits are major sources of flavonones and hesperidin is found in abundance (120-250 mg/lit) in orange juice. Quercetin occurs in its glycosylated form as rutin in fruits, vegetables and particularly onions are its rich source Anthocyanins are pigments of fruits such as cherries, plums, strawberries, raspberries, black berries and red currant and their content varies from 0.15 to 4.5 mg/g in fresh berries. Occurrence of some of the flavonoids is restricted to a few foodstuffs like the main source of isoflavonoids is soy, which contain ~1mg/g of genistein and daidzein and have received considerable attention due to their suggested role in prevention of cancer and osteoporosis. People who consume traditional diets rich in soy and tea rarely experience breast, uterus and prostate cancer. Although there are a range of potentially antimutagenic fruits, vegetables and cereals but their intake is generally below the level essential to protect from various mutagens .

As mentioned, research on specific phytochemicals in foods and their effects on disease risk is limited, but there's enough evidence—mostly from looking at the association between foods rich in phytochemicals and disease risk—to strongly suggest that consuming foods and beverages rich in these compounds may help prevent disease. However, it isn't known whether the health benefits are the result of individual phytochemicals, the interaction of various phytochemicals, the fiber content of plant foods, or the interaction of phytochemicals and the vitamins and minerals found in the same foods.

The consumption of whole grains rich with phytochemicals also is associated with lower blood pressure, which aids in the prevention of cardiovascular disease. Consuming four or more servings of whole grains daily is associated with a 23% lower risk of high blood pressure.

As consumption of whole grains increases, blood pressure generally decreases. Intervention studies, while inconsistent, also have found a positive association between whole grain intake and blood pressure. The consumption of cruciferous vegetables such as broccoli, cabbage, and cauliflower has been associated with a decreased risk of prostate, lung, breast, and colon cancers.31 Isothiocyanate phytochemicals found in cruciferous vegetables, especially sulforaphane in broccoli, which has been studied extensively, are believed to offer some degree of prevention.Therapeutic combinations of foods rich in phytochemicals that have yet to be identified could be effective for both cancer prevention and treatment. There's also evidence that some phytochemicals may have varying effects with respect to cancer risk, depending on an individual's age and genetic makeup. Isoflavones, for example, have estrogenlike effects and either may increase or decrease risk of breast There's a large volume of laboratory and animal research showing preventive effects of tea polyphenols against cancer of the skin oral cavity, esophagus, stomach, liver, pancreas, small intestine, colon, bladder, prostate, and mammary gland. Tea polyphenols have been shown to affect tumor suppression and cancer cell replication and also alter gene regulation.38 These effects usually are attributed to tea's catechin polyphenols. However, studies in humans haven't demonstrated a clear connection. The lack of a consistent effect in humans could be due to the fact that they don't consume the larger doses typically used in animal studies, the difficulty in obtaining accurate measurements of tea intake among human subjects, and genetic diversity among the human population that isn't present in research animals.

The polyphenols in cocoa have been found in laboratory studies to interfere with the initiation, promotion, and progression of cancer cells. While chocolate, especially dark chocolate, is rich in these polyphenols, it isn't known whether the same cancer-preventive effects would apply in the body and what an effective dose may be.

Dietary polyphenols may inhibit carbohydrate digestion and glucose absorption in the intestine, stimulate insulin secretion from the pancreas, modulate glucose release from the liver, activate insulin receptors and glucose uptake in insulin-sensitive tissue, and modulate intracellular signaling pathways and gene expression. Some studies have found that a reduced risk was strongest with the consumption of green leafy vegetables, which are rich sources of phytochemicals.

The polyphenols in tea and cocoa also may contribute to improved insulin sensitivity and lower type 2 diabetes risk. In a large population study from eight European countries, tea intake was associated with a significantly decreased risk of developing type 2 diabetes. Specifically, those who drank more than four cups of tea per day had a 16% lower risk compared with non-tea drinkers.

In a placebo-controlled trial with diabetes patients, those given flavonoid-enriched chocolate and supplemental isoflavones for one year experienced significantly reduced insulin levels, improved insulin sensitivity, and decreased total cholesterol, HDL ratio, and LDL cholesterol.

The consumption of flavonoid-rich foods such as berries and cocoa throughout life may hold the potential to limit, prevent, or reverse normal or abnormal deterioration in cognitive function in the aging brain.

Several studies have found an association between tea consumption and a lower risk of developing Parkinson's disease or delaying its onset by several years. It has been suggested that the association is due to its caffeine content, which also is a naturally occurring phytochemical, but flavonoid intake in general, and berries in particular, also have been linked to a reduced risk of Parkinson's disease.

Combining specific dietary flavonoids that are absorbed well and can penetrate the blood/brain barrier (which exists to prevent many substances in the blood from reaching the brain), thus preventing or slowing the production of damaging free radicals in the body, could help prevent and treat a variety of neurodegenerative disorders.59 But this uniquely effective combination of phytochemicals hasn't yet been identified.

The consumption of flavanol-rich cocoa has been found to improve cerebral blood flow, which is critical for optimal brain function and decreases in dementia and Alzheimer's disease. It's been suggested that consuming flavonoid-rich foods such as cocoa and berries throughout life may limit neurodegeneration and prevent cognitive decline.

Mechanism

Researchers have found that phytochemicals have the potential to stimulate the immune system, prevent toxic substances in the diet from becoming carcinogenic, reduce inflammation, prevent DNA damage and aid DNA repair, reduce oxidative damage to cells, slow the growth rate of cancer cells, trigger damaged cells to self-destruct (apoptosis) before they can reproduce, help regulate intracellular signaling of hormones and gene expression, and activate insulin receptors. In addition, there likely are health effects of phytochemicals that researchers haven't yet recognized.

Much laboratory research has focused on the antioxidant function of phytochemicals. However, their antioxidant activity is reduced in the body during metabolism, and the levels present in blood and tissue are fleeting and quite low. For many of the phytochemicals in food, their antioxidant effects on cell signaling and gene expression may be more important for health benefits than direct antioxidant activity, effects that can be seen even with low concentrations of phytochemicals in plasma and tissues.

In addition to being rich sources of phytochemicals, plant foods also are sources of fiber, vitamins, and minerals whose mechanisms have been more clearly elucidated. But identifying which individual compounds are responsible for the benefits associated with phytochemical-rich foods is difficult, if not impossible, because of the interactions that occur with vitamins, minerals, and fiber as well as among the phytochemicals themselves. The unique combination of these compounds may be the key to reduced disease risk, but that formula hasn't yet been identified and tested.

Recommendations

Even though many phytochemicals are believed to have disease-preventing properties, the lack of food composition data and the incomplete understanding of their absorption, metabolism, and interaction have prevented the Institute of Medicine from creating a Dietary Reference Intake (DRI) for any of them. In addition, unlike vitamins and minerals, these compounds aren't essential and are therefore not considered nutrients.

The research regarding phytochemicals is complicated by the fact that the effects of consuming phytochemical-rich foods may be most beneficial for people with more severe metabolic abnormalities, such as elevated blood lipids, type 2 diabetes, or obesity, and may not be as apparent in otherwise healthy populations. The complexity of the family of phytochemicals, their potential interactions, and the possible variations in levels found in any given food make it currently impossible to issue specific phytochemical guidelines. In addition, people eat a variety of foods and nutrients every day, each combination holding the potential for unique interactive effects, again making it extremely difficult to link a particular food, nutrient, or phytochemical to a specific health or disease outcome. More information is needed before dietary recommendations can be made.However, researchers have suggested that once sufficient data are established, a DRI should be developed for one or more of the groups of flavonoids.

At least three daily servings of whole grains, and including beans, legumes, roasted soybeans (1/4 cup cooked), and nuts or seeds (1/2 oz) as protein choices. There are no guidelines for coffee, tea, or cocoa consumption, but as long as their intake is factored into the day's intake of calories, moderate consumption of all three may offer additional health benefits. Bear in mind that dark chocolate is richer in phytochemicals than milk chocolate, and tea varieties (white, green, oolong, and black) have different amounts and types of phytochemicals that may provide different health benefits.

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