

Green Tea as a Functional Food – A Review

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Abstract—Functional foods are foods with positive health effects that extend beyond their nutritional value. All foods are functional to some extent because all foods provide taste, aroma and nutritive value. However, foods which provide added physiological benefits, which may reduce chronic disease risk or otherwise optimize health are called the functional foods. The physiologically active compounds in these foods, which have the capability to reduce the risk of chronic diseases, are called the bioactive factors.

Studies have shown that the polyphenol concentration of green tea is much more than that of black tea, which is approximately 30-40% as compared to 3-10% in black tea. This results in higher anti-oxidant activity and has an ability to help reduce the risk of chronic diseases as compared to black tea.

In this paper I have reviewed green tea and its use as a functional food, its bioactive factors and its possible health effects.

Keywords: Green tea, Catechin, Polyphenol, Anti-oxidant, Anti-inflammatory, Anti-microbial, Anti-cancer.

1. INTRODUCTION

People today have become very informed and are making knowledgeable informed choices, as far as their diet is concerned. We now understand that a healthy lifestyle embraces healthy food habits. This belief has led to the discovery of functional foods, as people realized that what Hippocrates had said some 2500 years ago is actually true “let food be thy medicine and medicine be thy food.” Hence, today there is a paradigm shift in the belief, food may provide more than just nutrients, that in order to immunize oneself from the challenges posed by the lifestyle diseases, functional foods have to be a part of the healthy lifestyle or those foods which will not only fulfil one’s nutritional requirements but would additionally protect one from various diseases.

Green tea or the freshly harvested, least processed and non-fermented leaves of the plant *Camellia sinensis*, can be considered as a functional food because of its proven anti-oxidant, anti-microbial, antifungal, cancer preventive, cardio-protective properties. The health benefits of green tea are mainly due to the presence of high levels of the bioactive compounds, the polyphenols, especially flavanol catechins. The main catechins in green tea are epicatechin (EC), epicatechin-3-gallate (ECG), epigallocatechin (EGC) and epigallocatechin-3-gallate (EGCG). Green tea also contains

vitamins and minerals such as ascorbic acid, riboflavin, niacin, folic acid, magnesium, potassium, manganese and fluoride.

2. WHAT ARE FUNCTIONAL FOODS

National Academy of Sciences Food and Nutrition Board, USA, defined functional foods as, “Any food that may provide positive health effects that extend beyond its nutritional value”. All foods are functional to some extent because all foods provide taste, aroma and nutritive value. However, foods which provide added physiological benefits, which may reduce chronic disease risk, called the functional foods are of great interest globally for health optimization [4].

Foods provide therapeutic benefits is clearly not a new concept. Up-till about the early 19th century the focus mainly was on identifying elements which had the potentiality to reduce deficiency diseases. However, towards the latter half of the 19th century the focus shifted to identifying the compounds in food that have the ability to reduce the risk of disease [4].

Some of the foods that have been identified as possessing the ability to help reduce the risk of chronic diseases are: Oats, soy, psyllium fibre, fatty fish, cranberry juice, green tea, garlic, probiotics and prebiotics, fermented dairy products, green leafy vegetables and tomatoes to name a few.

The physiologically active compounds in these foods, which have the capability to reduce the risk of chronic diseases, are called the bioactive factors.

3. FUNCTIONAL FOOD GREEN TEA - ITS BIOACTIVE FACTORS

Green tea or the freshly harvested, least processed and non-fermented leaves of the plant *Camellia sinensis*, can be considered as a functional food because of its proven anti-oxidant, anti-microbial, antifungal, cancer preventive, cardio-protective properties. The health benefits of green tea are mainly due to the presence of high levels of the bioactive compounds, the **polyphenols** especially **flavanol catechins**. These catechins make up to 80-90% of the tea flavonoids and about 40% of the water-soluble solids in green tea. The main catechins in green tea are epicatechin (EC), epicatechin-3-gallate (ECG), epigallocatechin (EGC) and epigallocatechin-3-gallate (EGCG). Apart from these, green tea also

contains protein, carbohydrates, important vitamins and minerals such as ascorbic acid, riboflavin, niacin, folic acid, magnesium, potassium, manganese and fluoride, trace amounts of lipids and certain volatile compounds. [16].

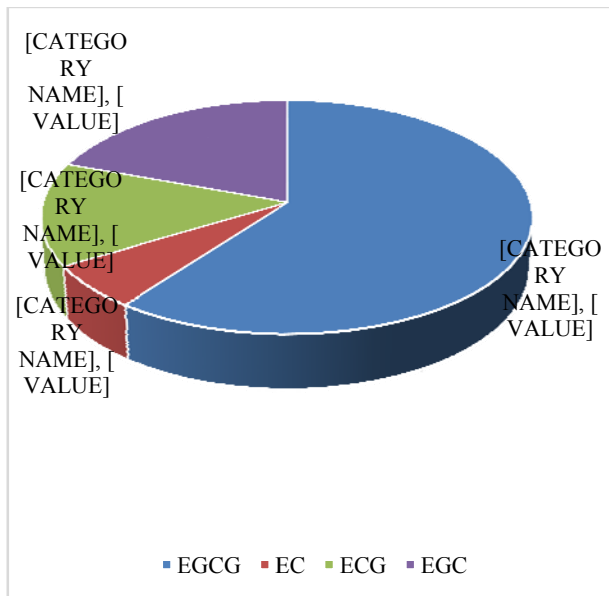


Figure 1 Composition of Tea Catechins

Studies have shown that the polyphenol concentration of green tea is much more than that of black tea, which is approximately 30-40% as compared to 3-10% in black tea. This results in higher anti-oxidant activity of green tea as compared to black tea.

Green tea is produced by steaming the young leaves of the plant at high temperatures thus inactivating the oxidizing enzymes and leaving the polyphenols intact. Polyphenols are powerful anti-oxidants and free radical scavengers. They chelate the metal ions and thereby decrease their pro-oxidant activity. The anti-oxidant effect of polyphenols depends on their structure and the position as well as the number of hydroxyl groups present. EGCG has the greatest potential for scavenging free radicals followed by EGC and EC, EC being the weakest of all. Also, the levels of EC and ECG are too low to be of any therapeutic importance.

The researches over a period of about 15-20 years have shown that green tea has a number of health benefits including, **anticarcinogenic, antimicrobial, anti-inflammatory, anti-oxidant properties and also cardiovascular health benefits besides others.**

4. ABSORPTION AND EXCRETION OF CATECHINS

The bioavailability of the green tea catechins is essential for them in order to be of any health benefit. Bioavailability is the measure of the presence of any substance in blood, urine or

tissues etc, after its uptake. Enough amounts of a substance are required at site for it to be of any health benefit [11].

The tea catechins are metabolized by the liver and the kidney and are excreted, mainly by the kidney. In the liver of humans and animals, catechins undergo glucuronidation, sulfation and O-methylation. These, then reach small intestines with bile, where they are broken down into phenolic acid and lactones. These are either absorbed in small intestines or excreted in bile or urine.

Glucuronidation is a major metabolic reaction, which takes place mainly in liver through which fat-soluble toxins are converted to water soluble compounds which can then be excreted in urine or bile. Research has shown that this detoxification process is increased by 100% in experimental rats, on drinking green tea as the only liquid. It has therefore been, proposed by scientist that increased glucuronidation may contribute to the anti-carcinogenic effect of green tea [11].

5. HEALTH BENEFITS OF GREEN TEA

Consumption of green tea has been shown to provide protection against stroke, liver disease, bacterial infection, viral infection cancer and also to lower risk of osteoarthritis. Green tea catechins exert a protective effect on mammalian hepatic cells, leading to its use in the therapeutics of hepatitis.

5.1 Anticancer Effects

Green tea polyphenols function dually in cancer prevention, first by effecting the carcinogen metabolism and secondly, by preventing the damage of DNA and also repairing the DNA damaged by carcinogens

Tea polyphenols decrease the levels of those enzymes which activate carcinogens and raise the levels of those enzymes which detoxify carcinogens.

Number of studies have shown that tea and its bioactive factors inhibit carcinogen induced DNA damage. However, two studies conducted on smokers, one studying the effects of green tea consumption on the oral cells of smokers [14] and another study on the cellular and molecular effects of increased tea consumption on oxidative DNA damage [5] of smokers showed inconsistent results, while the results in animal studies showed positive effects of green tea consumption on prevention of damage to cell DNA. The first study concluded that a regular intake of green tea might protect smokers from the DNA damage and reduce the risk of cancer and other diseases caused by the free radicals produced due to smoking. The second study showed that while green tea was administered, DNA damage caused by smoking was decreased, cell growth repressed as also cell death that is apoptosis, indicating that green tea consumption reduced the number of damaged cells.

Various studies have also shown that green tea consumption is effective in the prevention of lung and colon cancer.

As the levels of tea polyphenols in blood and tissue that can be achieved through oral consumption are quite low, the effectiveness of oral consumption of green tea in prevention of cancer is limited. Among many approaches, the efficacy of the administering tea polyphenols along with other agents is being explored.

However, many other epidemiological studies have shown that green tea polyphenols are useful in both the primary prevention (prevention and delay in cancer onset) and tertiary onset (cancer metastasis and recurrence).

Through these studies it was shown that consumption of more than 10 cups of green tea (120ml/cup) was associated with reduced incidence of lung, colorectal, stomach and liver cancers. As discussed earlier the 4 main green tea catechins are EGC, EGCG, EC and ECG. Studies at the National Cancer Center Research Institute in Tokyo and Saitama Cancer Center Research Institute have shown that out of these 4 only ECG, EGC, and EGCG exhibit cancer preventive activity while EC is mostly inactive, and EGCG is the most active of all [15].

Some other studies also reported similar results. One such study was done by Dr Nakachi and Dr Imai at Saitama Cancer Center and Research Institute in 1986. In this study, a survey of about 8552 individuals above the age of 40 years was conducted. This survey included their lifestyle and daily habits of green tea consumption. After 1986, for the next 10 years in the follow up study about 419 cancer patients were found, out of which 244 were males and 175 were females. These 419 subjects were then divided in three groups on the basis of their daily tea consumption habits: 1st group contained those who drank less than 3 cups green tea per day, 2nd group was composed of subjects drinking between 4 and 9 cups and the 3rd group was of those subjects, who drank more than 10 cups of green tea per day. Also, the average age of the onset of cancer for each was obtained. It was observed that cancer onset in females who drank more than 10 cups of green tea per day was 7.3 years later than those who drank less than 3 cups daily and for males the onset was 3.2 years later for those who consumed more than 10 cups daily compared to those who drank less than 3 cups. The onset age difference between males and females was attributed to higher consumption of tobacco by males. Through this cohort prospective study, it was shown that consumption of more than 10 cups of green tea (120ml/cup) results in the delay of cancer onset in general population [7].

One study also reported that consumption of more than 5 cups per day was associated with significantly reduced risk of recurrence of stage I and II breast cancer.

The polyphenols in green tea have been reported to modulate various cancer-related molecules. Both cell growth and induced apoptosis were reported to be inhibited by green tea polyphenols in different types of malignancies. Additionally, polyphenols in green tea also modulate the function of cancer-related signalling molecules. The different cancer-related

processes and factors through which green tea polyphenols show the anti-cancer effect include: DNA methylation, histone modification, micro RNA and protein synthesis. The effect of ECGC on the pathological behaviour of stem cells has also been reported in many types of cancers such as lung and colorectal cancers [18].

However, some epidemiological studies did not show any significant relationship between green tea consumption and risk of bladder cancer. The discrepancies could be due to difference in race, country and the unit of measurement of green tea, also due to certain influencing factors such as smoking, amount of tea consumption on a daily basis and other beverages consumed [18].

5.2 Antimicrobial Effects

Antibacterial and antiviral effects of green tea polyphenols have been reported through many epidemiological studies which has caused researchers to look at the possibility of using green tea in antimicrobial therapy and for prevention of infection [18].

Four main mechanisms through which the **antibacterial** agents attack micro-organisms have been seen:

- Inhibiting cell wall synthesis
- Inhibiting protein synthesis
- Inhibiting nucleic acid synthesis or
- Inhibiting metabolic pathways

Antibacterial properties of green tea can be attributed to the catechins binding with the lipid layer in the bacterial cell wall, thus inhibiting cell wall synthesis, green tea polyphenols inhibit the fatty acid synthesis in microbial cells and so inhibit the production of toxic metabolites by the bacterial cells. Bacterial cell damage causes inhibition of the ability of bacterial cell to bind to the host cell. Additionally, green tea polyphenols also interfere with the bacterial DNA replication, block folate production by bacterial cells and also reduce the ability of the micro-organism to produce sufficient energy for its survival. Studies have proven that there is a great potential for the use of green tea in the antimicrobial therapy.

Additionally, green tea catechins also show some effects which may contribute to the total anti-microbial effect in the infected individuals, such as inhibition of inflammation especially the vascular inflammation caused by oxidative stress.

5.3 Anti-inflammatory Effects

Inflammation is a part of the of the body's defence mechanism and happens in response to an injurious stimulus such as physical injury, infection, due to a particular irritant or foreign material and toxins, etc. Where as the body has the ability to heal acute inflammation in a matter of a few weeks, chronic inflammation may last for months or even years. World Health

Organisation has ranked chronic inflammatory diseases as a greatest threat to human health. [12] While inflammation is a part of the body's normal healing process, chronic inflammation can cause loss of tissue function, organ failure and can be debilitating. Chronic inflammatory diseases include diabetes, cardiovascular disease, metabolic syndrome, arthritis, allergies, chronic obstructive pulmonary disease and even cancer.

Unhealthy diet and sedentary lifestyle have been on a rise in recent years, leading to many health problems including metabolic syndrome, obesity, diabetes and fatty liver to name a few [6]

Green tea polyphenols have been shown as powerful antioxidants, which play an important role in the modulation of the signalling pathways involved in inflammation process. The features of the inflammatory response are immune cell aggregation at the site of inflammation, release of proinflammatory cytokines and production of reactive oxygen and nitrogen species. Several clinical trials have shown that green tea polyphenols as a part of mixed diet, show a protective effect against oxidative damage by inhibiting free radical and reactive oxygen species (ROS), formation.

One of the leading causes of inflammation is the denaturation of tissue protein which may also cause production of auto-antigens. In an in-vitro study for the evaluation of the anti-inflammatory effects of green tea vs black tea, it was shown that green tea had a more pronounced anti-inflammatory effect. The effect could be attributed to the presence of higher quantity catechins or simple flavanols present in green tea as compared to that present in black tea. During processing of the tea leaves undergo oxidation and the flavanols get polymerised to theaflavins and thearubigins, and thus lose their effectiveness. The effect was also due the synergistic effect of the flavanols present rather than any single component[2]

Various mechanisms have been proposed to explain the anti-inflammatory effect of green tea. In one study it was found that the polyphenols in green tea reduced the synthesis of interleukin-17 (a pro-inflammatory cytokine) and increased synthesis of IL-10 (a cytokine with potent anti-inflammatory properties), by the lymphocytes during chronic inflammation. This reduction in the synthesis of IL-17 helps in the inhibition of several processes related to the development of chronic inflammatory diseases.

5.4 Anti-oxidant Effects

Green tea polyphenols protect against ROS (reactive oxygen species) and react with them to form more stable phenolic compounds. Due to the presence of galloyl group in EGCG, it has the ability to react with O_2^- and OH^- . The concentration of EGCG is comparatively high in green tea (approx. 59%) as compared to oolong and black tea giving it a higher anti-oxidant capacity. The anti-oxidant capacity of teas is measured by oxygen radical absorbance capacity (ORAC) assays. A

positive correlation exists between the polyphenolic content of tea and ORAC. The anti-oxidant or reducing capacity of a substance of plant origin is measured by its capability to donate hydrogen atom or free electron to the free radicals. Catechins and gallic acid both possess the ability to both reduce the free radical and then scavenge or deactivate the unstable compounds thus formed and chelate the redox-active transition metal ions. The antioxidant activity of the components in green tea has been shown to be in the following order; EGCG > ECG > EGC > EC. [9, 13]. The antioxidant capacity of plasma has been seen to increase by 4% after 40 minutes of drinking 400 ml of hot green tea extract.

According to some literature, anti-oxidant properties of tea polyphenols do not fully account for their chemoprotective and apoptotic activities. Green tea polyphenols also act as pro-oxidants by generating hydrogen peroxide (H_2O_2). Green tea polyphenols also possess pro-oxidant properties, they are very unstable and produce ROS by undergoing auto-oxidative reactions which are copper-initiated, including but not limited to H_2O_2 . The ROS act as the DNA cleaving agents and thus act to increase apoptosis in cancer cells. Where the capacity of EGCG to produce ROS is more than EC [1].

5.5 Cardiovascular Health Effects

Cardio Vascular Disease is a disease involving a lot many features, such as lipid metabolism related abnormalities, disturbed vascular tone, inflammation, platelet aggregation, and vascular dysfunction. Green tea catechins have been seen to be having a positive effect on all these parameters including lipoprotein oxidation, deranged lipid profile, vascular inflammation in addition to blood platelet aggregation, through its anti-oxidative and anti-inflammatory effects.

Many studies, whether clinical trials, epidemiological studies or even some experimental studies have all established a positive correlation between green tea consumption and cardiovascular health. In one very famous study, Ohsaki Study, which was a Population-based Prospective Cohort Study, with 40530 participants, started in 1995 and results reported in 2006, the association between green tea consumption and mortality due to CVD, cancer and other causes were examined. After analysis it was found that green tea consumption was inversely associated with mortality from cardiovascular disease, cancer and all causes and that the inverse relationship was more pronounced in women compared to men, especially those consuming more than 5 cups or above (500ml or more) of green tea per day. Also, within the CVD mortality, a more pronounced inverse association was observed for stroke mortality.

In another study data was used from the China Kadoorie Biobank (CKB), an ongoing cohort of 0.5 million adults to prospectively examine the association between regular consumption of green tea and the risk of Ischemic Heart Disease (IHD). In this large prospective cohort study an association between tea consumption and reduced risk of IHD

was reported. People who consumed green tea daily showed a reduction of about 8% relative risk of IHD and 10% lower risk of any major cardiovascular event. The effects were more pronounced in people who had been drinking tea for more than three decades, had a normal or lower than normal BMI and who did not have any chronic disease otherwise.

6. CONCLUSION

The health benefits and therapeutic uses of green tea are due to the presence of the phenolic compounds, which are present in greater amounts in green tea compared to either oolong or black tea. The availability of these compounds is dependent on their extraction from the leaves which depends on the time taken and temperature reached, for its preparation. Aqueous solution prepared at just before boiling point temperature and steeping of leaves for 3-4 minutes, has been shown to be effective in improving the availability of its phenolic compounds. Phenolic compounds have been shown to work better in hot aqueous solutions at alkaline pH. Also, addition of milk may prevent phenolic compounds to act as anti- and pro-oxidants mainly due to the fact that they may bind with milk protein and are unable to form hydrogen peroxide.

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