

A comprehensive review on phytochemicals constituent Green tea and their correlation with its medicinal benefits

Gund Samarth Somnath*, Kedar Tukaram K, Bais Sanjay K

Fabtech College of Pharmacy, Sangola, Maharashtra, India

Corresponding Author: Gund Samarth Somnath

Abstract

Many conservation organisations are advocating for the cultivation of wild medicinal plants in response to the growing demand and popularity of these plants. One of the oldest & most widely used therapeutic drinks in the world is Green tea. The leaf of the "*Camellia sinensis*" plant is used to make this product. It can be converted into a beverage with numerous universal health benefits, or the leaves can be extracted for medicinal purposes. According to reports, green tea contains thousands of bioactive elements, nearly all of which are polyphenols. According to recent human research, green tea may help lower the risk of cardiovascular disease and some types of cancer. It may also recover oral health and other physiological processes like body weight control, antiviral & antibacterial activity, and an antihypertensive effect. These compounds are important for the inhibition & treatment of a variability of illnesses. This literature review's objective was to demonstrate the medicinal qualities of the herb "green tea."

Keywords: *Camellia sinensis*, Green Tea, Polyphenol, Anti-hypertensive, Anti-viral, cardiovascular disease etc

Introduction

One of the most widely consumed drinks worldwide is tea. The *Camellia sinensis* plant is the source of tea. For humans, green tea is a natural treasure. It is the most popular and second-oldest beverage in the world. One of the most widely consumed drinks worldwide is tea. The plant *Camellia sinensis* is the source of tea. [2]

White, green, oolong, and black are the four basic kinds of tea that are manufactured. Oolong tea is created as of partially fermented leaves, black tea is made from fully fermented leaves, white tea is formed from extremely young tea leaves or buds, and green tea is made from mature, unfermented leaves. [3] In the 17th century, India began exporting green tea to Japan. The globe produces an estimated 2.5 million tonnes of tea leaves yearly, of which 20% are made into green tea, which is generally consumed in Asia, some regions of North Africa, the United States, & Europe. [4]

Black tea and green tea undergo various manufacturing processes. In order to prevent fermentation and create a stable, dry product, freshly plucked leaves are immediately steamed to make green tea. The enzymes that break down the colour pigments in the leaves are destroyed during the steaming process, which keeps the tea green throughout the rolling and drying steps that follow. [5]

It is advised to consume items containing catechins in the daily diet because of their many health-promoting qualities. Green tea contains polyphenol molecules (catechins) that dimerise to create Thea Flavin's, leading to varying biological activity. Plants have been a model source of drug since ancient times. Ayurveda and other Indian literature highlight the use of plants to treat a range of human illnesses. Thousands of India's more than 45,000 plant species are thought to have medicinal properties. [6]



Fig 1: Tea Plant. [7]

Chemical Composition of Green Tea

Green tea contains approximately 15-20% protein, counting amino acids like l-theanine. [8] The processing of *Camellia sinensis* leaves results in distinct effects, physiologically active substances, and health-promoting benefits. [9] Green tea contains xanthine bases, including theophylline and caffeine. [10] Green tea's chemical composition varies based on climate conditions, soil qualities, genetic strain, leaf plucking season location, processing, and storage. [11] The catechins account for 80-90 percent of the flavonoids & around 40% of the water-soluble solids in green tea. Green tea covers more catechins than other teas, primarily due to how it is processed after harvesting. [12]

Epicatechin, epigallocatechin, epicatechin-3-gallate, and EGCG are the four types of catechins that are primarily found in green tea. Both the quantity and quality of catechins are influenced by the preparation techniques; variations in variety, origin, and growing conditions [1] also affect the amount of catechins in the original tea leaves. [13, 14]

The chemical composition of green tea is complex: proteins

(15-20% dry weight), whose enzymes constitute an important fraction; amino acids (1-4% dry weight) such as theanine or 5-N- ethylglutamine, glutamic acid, tryptophan, glycine, serine, aspartic acid, tyrosine, valine, leucine, threonine, arginine, and lysine; carbohydrates (5-7% dry weight) such as cellulose, pectins, glucose, fructose, and sucrose; minerals and trace elements (5% dry weight) such as calcium, magnesium, chromium, manganese, iron, copper, zinc, molybdenum, selenium, sodium, phosphorus, cobalt, strontium, nickel, potassium, fluorine, and aluminium; and trace amounts of lipids (linoleic and α -linolenic acids), sterols (stigmasterol), vitamins (B, C, E), xanthic bases (caffeine, theophylline), pigments (chlorophyll, carotenoids), and volatile compounds (aldehydes, alcohols, esters, lactones, hydrocarbons). [15, 16, 17, 18]

Green tea is an unfermented tea and its chemical composition is quite different from black tea.

Table 1: Chemical Composition

Sr. No.	Types of Ingredients	Ingredients
1.	Amino Acid	L-theanine
		Tyrosine
		Serine
		Glycine
		Valine
2.	Carbohydrates	Glucose
		Cellulose
		sucrose
3.	Volatile compound	Alcohols
		Esters
		Hydrocarbons
		Aldehydes
4.	lipids	Linoleic Acid
		α -linolenic acid
5.	Vitamins	vitamin A
		vitamin B2
		vitamin B3
		Vitamin C
		Vitamin E
		Vitamin K
6.	Tracer Elements	Magnesium
		Chromium Manganese
		Calcium
7.	Phenolic acid	Gallic acid

Phytochemical constituents present in Green tea1.

Catechin: The typical green tea flavonoids are called catechins. Compared to oolong or black tea, green tea has a significantly higher concentration of catechins. [19]

Green tea is the primary dietary source of catechin gallates and is high in polyphenols, of which roughly 70% are catechins. The amounts of the principal flavan-3-ols, the collective term for the catechin group of chemicals, and the various classes of phenolics in green tea are listed above the chemical structures of the primary green tea catechins. Catechins can also be found in red wine, grapes, apples, and chocolate. [20] A cup of green tea contains 20-200 mg of EGCG, one of the most prevalent catechins in green tea. According to references Higdon and Freil, it has also been proposed that it is one of the most potent substances in green tea, mediating the majority of its biological effects. [21]

Additionally, catechins serve as iron and copper ion chelators. The antioxidant potential of green tea is significantly influenced by the particular chemical structure of its polyphenols, which are defined as having at least five hydroxyl groups. The di/tri-hydroxy structure of the B and D rings allows for the chelation of transition metal ions. [22] Similar to their antioxidant qualities, catechins' pro-oxidizing qualities are also influenced by elements like the molecule's hydroxyl group count. Both electrophilic quinones and reactive oxygen species harm cellular molecules during the polyphenol oxidation process. This element has a key role in the etiopathogenesis of cancer and degenerative illnesses. [23]

Mode of action of catechin-

The most researched catechin derivative to date is EGCG. Green tea's catechin content is mostly determined by its kind, the cultivation and leaf processing techniques, as well as the temperature and brewing duration. Research indicates that catechins are most stable in the pH range of 4 to 6. [24]

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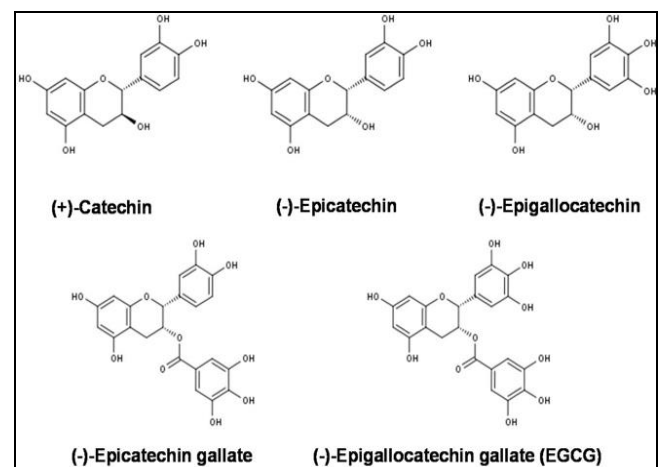


Fig 2: Structure of different types of Catechin. [26]

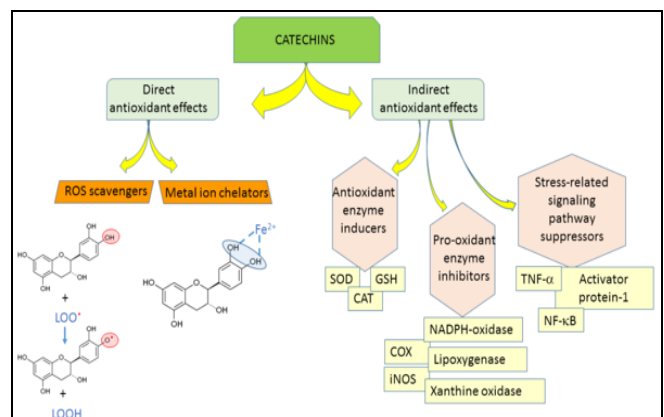


Fig 3: Mode of action of Catechin. [27]

Caffeine

The primary ingredient that gives tea beverages their unique and appealing flavour is caffeine. Additionally, it is a potent antioxidant that boosts the beverage's antioxidant capacity. The age of the leaves and the time of harvest may have an impact on its level; the older the leaves, the lower the caffeine concentration. The type of tea, the weather during the growing season, and the brewing technique all affect the caffeine concentration.^[28]

Another crucial element in assessing the quality of green tea is its caffeine content. The primary methyl xanthine that makes up the tea alkaloids is caffeine, which is acknowledged as a significant quality factor because of its stimulative impact. Contrary to these green tea catechins, caffeine can noticeably improve the flavour of tea.^[29]

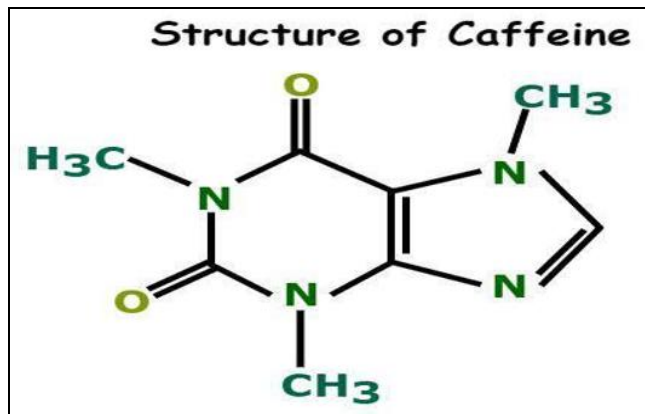


Fig 4: Structure of Caffeine.^[30]

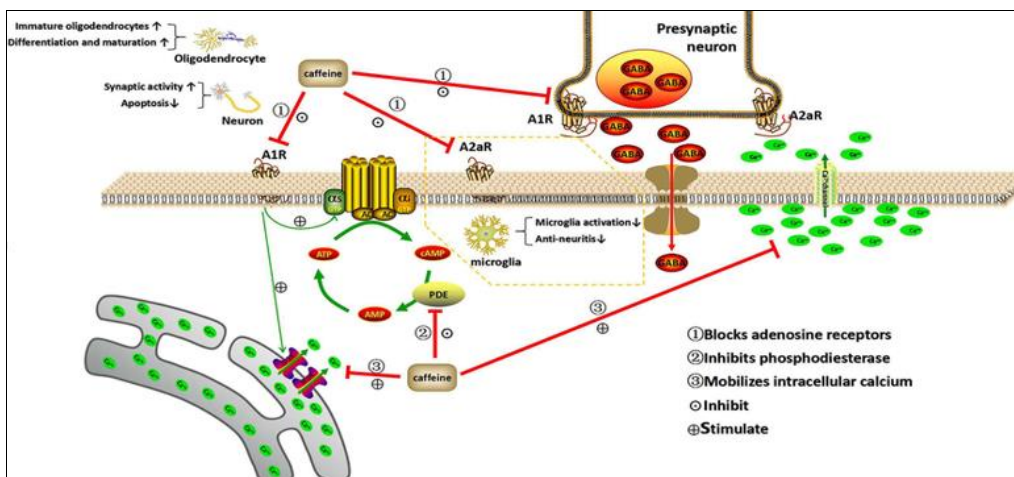


Fig 5: MOA of Caffeine

Flavonoids

Flavonoids are 15-carbon polyphenolic substances with two aromatic rings joined by a bridge of three carbons. The flavones, flavonols, flavan-3-ols, isoflavones, flavanones, and anthocyanidins are the principal subclasses of these C6-C3-C6 compounds. The chalcones, dihydrochalcones,

dihydroflavonols, flavan-3,4-diols, coumarins, and auronones are additional flavonoid families that are less important dietary components. Many substituents can be added to the basic flavonoid skeleton. Most flavonoids are found in nature as glycosides instead of aglycones.^[32, 33, 34]

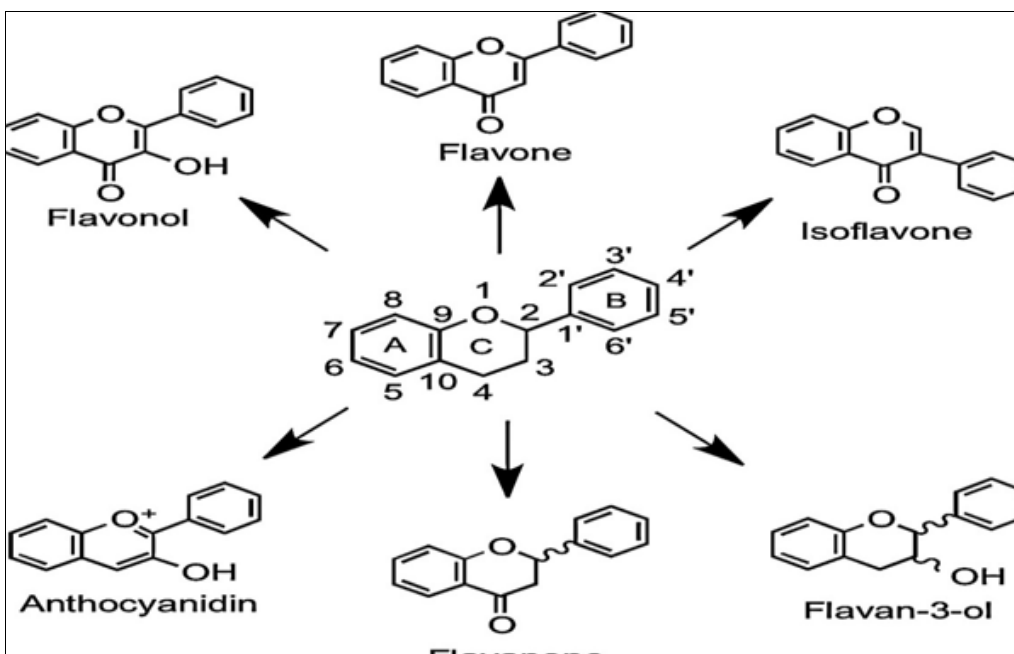


Fig 6: Structure of Flavonoid's.^[35]

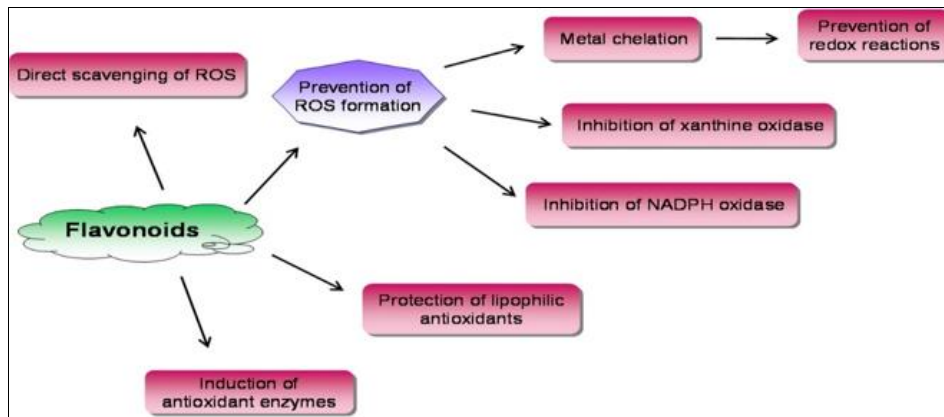


Fig 7: General MOA of Flavonoid's. [36]

Non flavonoids

The C6-C1 phenolic acids are among the nonflavonoids that are important for nutrition. The most prevalent phenolic acid is gallic acid, which is found in gallotannins, which are small dietary components, as complex sugar esters as 2-O-

digalloyl-tetra-O-galloyl-glucose. A variety of foods include the related ellagic acid-based ellagitannins, including punicalagin and sanguin H-6. [37]

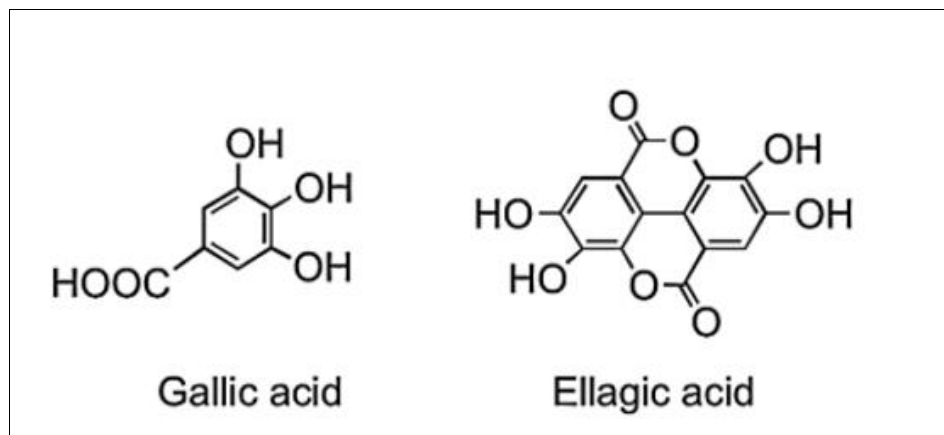


Fig 8: Structure of Non Flavonoid's [38]

Parameters Affecting Chemical Composition

The grinding procedure and, eventually, the powdered form of match are also responsible for its noticeably high antioxidant capacity. [39]

The agro climatic circumstances during growth, such as the quantity and distribution of sunny and rainy days, fertilisation, and any plant protection measures, also have an impact on the amount of health-promoting compounds, including polyphenols.

Shown that the polyphenol content of infusions prepared from powdered tea leaves is higher than that of infusions made from steeped tea leaves. Therefore, the extraction of polyphenolic chemicals may be accelerated by the grinding process itself. [40]

Different Between Black tea & Green Tea

Through apoptosis induction, fatty acid synthase down-regulation, and COX-2 inhibition in cellular and animal models, theaflavin 1 has been shown to inhibit lung carcinogenesis. By controlling the BAX and p53 proteins in the HeLa and WI38VA cervical cancer cell lines, theaflavin 2 caused cell death. [41]

The chemical makeup of black tea and the fermentation and oxidation processes are the main areas where it differs from green tea. Theaflavin (TF1), Theaflavin-3-monogallate (TF2a), Theaflavin-30-monogallate (TF2b), and Theaflavin-

3,30-digallate (TF3) are among the many catechins that are abundant in black tea, much like in green tea. Both the individual theaflavins and the molecular mechanism of black tea extraction are covered in several articles. The information indicates that black tea contains phenolic acids, flavanols, tearubigins, amino acids, proteins, methylxanthine, mineral compounds, and volatile substances in addition to catechins and theaflavins. [42]

Notably, black tea's anti-estrogenic properties may considerably lower women's risk of developing malignant neoplasms.



Fig 9: Different between Black Tea & Green Tea. [43]

Health benefits of Green tea

Green tea's inherent antioxidants are what give it its health advantages such as polyphenols, a diverse group of substances that make up up to 30% of green tea's dry

weight. The presence of natural antioxidants, such as polyphenols, which make up up to 30% of the dry weight of green tea, is what gives it its health advantages. [44, 45]

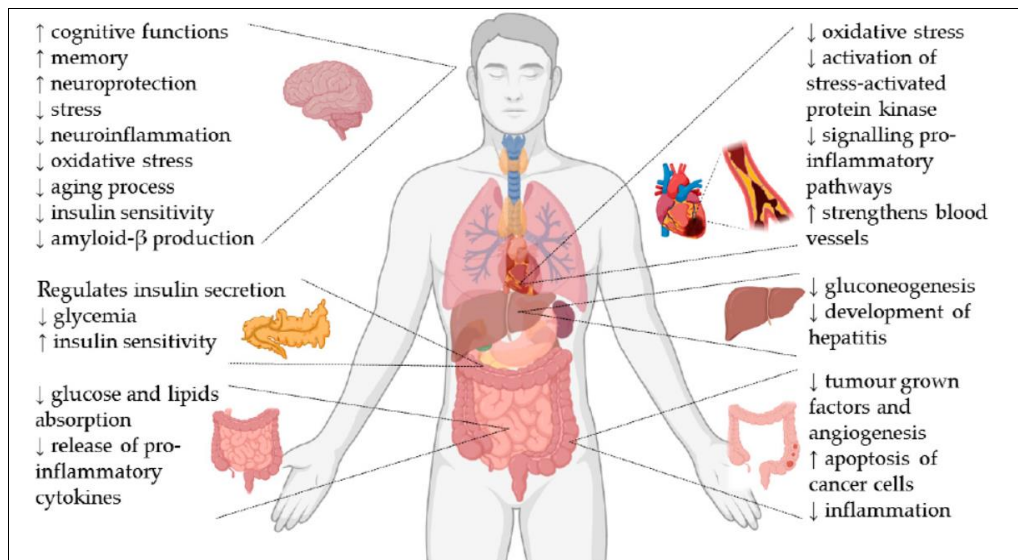


Fig 3: Health-promoting properties of the main bioactive compounds of Green tea. [46]

Cardiovascular Function-

Green tea use may lower the incidence of cardiovascular disease, according to epidemiologic research, although the exact mechanisms are still unknown. Results from clinical investigations on the impact of green tea on blood pressure, cholesterol, and coronary artery disease are not always consistent. [47]

Green tea drinking was found to be negatively correlated with the death rate from cardiovascular disease in a prospective cohort study involving over 40,000 Japanese individuals. 10 Women who drank five or more cups a day were 31 percent less likely to die from heart disease. 10 The incidence of stroke was considerably lower among participants who drank five or more glasses daily. [48]

By lowering oxidative stress and avoiding cardiac inflammatory alterations, EGCG may have a protective impact on the heart muscle. By preventing the activation of stress-activated protein kinase and signalling pathways that trigger the inflammatory response, EGCG may be able to protect the heart muscle in surgical patients who are vulnerable to ischaemic injury. [49]

Regulation of Carbohydrate Metabolism-

The hypoglycemic action of catechins and other polyphenolics is demonstrated by their impact on the parameters of glucose metabolism. EGCG content may prevent starch breakdown, reducing the abrupt release of glucose in the gastrointestinal tract and perhaps lowering blood glucose levels. EGCG may have the ability to improve insulin sensitivity and prevent the gastrointestinal system from absorbing glucose and fats by blocking gluconeogenesis. [50]

Anticarcinogenic Effects

Consuming substantial doses of EGCG may contribute to reducing the incidence of colorectal cancer, mainly due to blocking tumour development factors. Furthermore, EGCG can cause cancer cells to undergo apoptosis and impede their proliferation. Reducing blood cholesterol levels and

increasing tissue sensitivity to insulin and leptin may prevent obesity-related carcinogenesis. Green tea extract supplements may also stop recurrent adenomas, which most of the time can develop into colorectal malignancies. [51] Inhibition of gallbladder and bile duct cancer cell growth and proliferation, along with a lower risk of biliary duct cancer, are further research findings pertaining to EGCG administration. [52]

Prevention of Neurodegenerative Disorders-

Caffeine may indirectly prevent the ageing of the brain by reversing oxidative processes and lowering neuroinflammation, hence preserving normal brain function. Memory impairment may result from oxidative stress, which can cause damage to neurones. With its anti-inflammatory properties, particularly in the hippocampus, caffeine administration may stop this condition from developing. Reduced amyloid-β deposition in the brain is intimately linked to caffeine's beneficial effects on the nervous system and prevention of neurodegenerative disorders. Lipopolysaccharide (LPS)-induced systemic inflammation is a major factor in neurodegenerative illnesses. [53, 54]

Anti-viral effects-

In cell culture, it was discovered that EGCG and ECG from Green tea were strong inhibitors of influenza virus replication. All studied influenza virus subtypes, including A/H1N1, A/H3N2, and B virus, showed this impact. Quantitative research showed that whereas EGC did not exhibit a comparable impact, large concentrations of Green tea similarly inhibited viral RNA synthesis in cells. Likewise, EGC from Green tea was less efficient than EGCG at inhibiting neuraminidase activity.

The influenza virus's surface contains the antigenic glycoprotein enzyme neuraminidase. Neuraminidase performs tasks that facilitate the effective release of viruses from cells. [55]

Anti-Inflammatory Effect-

Many disorders are characterised by an inflammatory response. In addition to performing signalling roles that promote inflammation, it may result in the generation of excessive amounts of substances that promote the production of reactive oxygen species (ROS), which can harm cell structures and cause long-term disturbance in the body's overall functioning. Anti-inflammatory and antioxidant drugs primarily work by scavenging reactive oxygen species (ROS) to prevent inflammation-related signalling.^[56]

By scavenging NO, peroxynitrite, and other ROS/RNS, Green tea inhibits the transfection of NF- κ B and AP-1 to downregulate the expression of iNOS and COX-2. It also reduces the synthesis of inflammatory factors to exhibit anti-inflammatory actions. It has been shown that Green tea may suppress the respiratory passage epithelial cells' IL-8 synthesis, hence lessening the intensity of the respiratory passage inflammatory response. IL-8 can also boost the activation of reactive oxygen species and encourage neutrophil aggregation.^[57] Furthermore, Tang *et al.* contended that Green tea inhibits the JAK1/2 tyrosine kinase signalling pathway in vascular endothelial cells, thereby downregulating the production of proinflammatory genes regulated by the P2X4 receptor.^[58]

Antioxidant Effect

One of the most important processes for human health is oxidation. We classify Green tea as an antioxidant based on its chemical composition. The phenol rings in the Green tea structure scavenge free radicals and trap electrons.^[59]

As an antioxidant, EGCG has been shown to enhance mitochondrial performance and to efficiently prevent oxidative stress-induced protein tyrosine nitration in blood platelets.

Nonetheless, some research indicates that high concentrations of EGCG might induce self-oxidation and act as a prooxidant by generating hydroxyl radicals, hydrogen peroxide, and quinonoid intermediates that cause cytotoxicity.^[60]

Antifibrosis Effect-

In order to suppress the expression of specific genes, Green tea primarily prevents NF- κ B from moving from the cytoplasm to the nucleus. A serious side effect of chronic liver illnesses, hepatic fibrosis can eventually result in cirrhosis, liver failure, and even liver cancer.

The primary producers of extracellular matrix in chronic liver illness are atic stellate cells, which will proliferate and secrete extracellular matrix excessively as hepatic fibrosis develops, exacerbating the condition.^[61]

Oral Disease Treatment-

EGCG is mostly used in oral therapy because of its anti-inflammatory properties and capacity to prevent bone absorption. Pulpal necrosis from bacterial infection is one of the well-known causes of tooth extraction, as it can cause bone resorption and an inflammatory reaction at the tooth's periapical region.^[62]

Collagen membranes cross-linked with EGCG may be useful for guided bone regeneration (GBR). In dental implant operations, where collagen membranes are typically utilised, GBR is an efficient technique to increase the alveolar bone's inadequate volume.^[63] Cross-linking

compounds are frequently employed to enhance the mechanical characteristics of pure collagen membranes. Because of its anti-collagenase properties, EGCG may be a useful cross-linking agent for collagen membranes. Thus, EGCG-modified collagen membranes have also been the subject of some research. Chuet *al.* created a unique collagen membrane modified with EGCG that had better osteoblast cell adhesion and favourable mechanical properties.^[64]

Regulation of Carbohydrate Metabolism-

The hypoglycemic action of catechins and other polyphenolics is demonstrated by their impact on the parameters of glucose metabolism. EGCG from Green tea concentration may prevent starch breakdown, reducing the abrupt spike in blood sugar levels. EGCG may have the ability to improve insulin sensitivity and prevent the gastrointestinal system from absorbing glucose and fats by blocking gluconeogenesis.^[65]

Table 2: Phytochemical constituents of Green tea with Pharmacological Activity.^[66, 67]

Sr.No.	Phytochemical constituents	Pharmacological Activity
1	Catechin	Anti-inflammatory Anti-neoplastic reducing blood lipid parameters
2	Caffeine	CNS stimulant anti-inflammatory effects
3	Quercetin	Regulation of carbohydrate metabolism
4	Phenolic acids	improving insulin sensitivity
5	Rutin	Cardioprotective

Discussion and Conclusion-

As shown in above table of phytochemical, Green tea has a variety of possible health advantages because of its distinct mixture of bioactive components. It has higher levels of phenolic acids, quercetin, rutin, thiamine, and chlorophyll than other types of Tea.

The flavanol group of polyphenols called catechins, which can make up as much as 30% of the dry leaf weight, is remarkably abundant in fresh tea leaves. Flavonols and their glycosides, as well as depsides such chlorogenic acid, coumarylquinic acid, and theogallin (3-galloylquinic acid), which is specific to tea, are examples of other polyphenols. In addition to extremely trace levels of the other common methylxanthines, theobromine, and theophylline, caffeine is present at an average level of 3%. This flavonoid content is beneficial in varieties of diseases like cardiovascular disfunctioning, arthritis etc.

It has been shown that EGCG has inhibitory effects in many aspects of abnormal changes, including antioxidant, anticancer, anti-inflammatory, anticollagenase, and antifibrosis effects, which appear in its wide functional range. People believe that drinking green tea is good for their health (Figure). EGCG may protect organs or tissues from a variety of illnesses to some degree.

As we included above catechin assist treatment and cancer prevention by preventing tumour growth factors and causing cancer cells to undergo apoptosis.

Stopping the development of cancer cells and avoiding metastasis EGCG improves tissue sensitivity to insulin and leptin, lowers blood lipid levels, inhibits tumour angiogenesis, has antioxidant properties, and suppresses

inflammatory processes that lead to transformation, hyper proliferation, and the start of carcinogenesis.

Also Quercetin of green tea enhances insulin sensitivity, controls insulin production, inhibits glucose absorption, and results in lowering of blood sugar level which shows its benefit as anti-diabetic agent as well.

We concluded that with the help of our distinct review the green tea containing varieties of photochemical constituents such as Quercetin, Vitamins, Minerals, EGCG, Catechin, Caffeine etc. shows combined effects on different types of diseases. Green tea contain larger amount of all these photochemical constituents as compare to other plants that why it shows quick effect in short period of time.

References

- Gomikawa S, Ishikawa Y, Hayase W, Haralake Y, Hirano N, Matuura H, *et al.* Effects of ground tea drinking for 2 weeks on the susceptibility plasma and LDL to the oxidation *ex vivo* in healthy volunteers. *Kobe J Med Sci.*,2008;54(1):E62-72.
- Steinmann J, Buer J, Pietschmann T, Steinmann E. Anti-infective properties of epigallocatechin-3-gallate (EGCG), a component of green tea. *Br. J. Pharmacol.*,2013;168:1059–1073.
- Gupta DA, Bhaskar DJ, Gupta RK, Karim B, Jain A, Dalai DR. *et al.* Green tea: a review on its natural anti-oxidant therapy and cariostatic benefits. *Biol. Sci. Pharm. Res.*,2014;2:8–12.
- Moyers SB, Kumar NB. Green tea polyphenols and cancer chemoprevention: multiple mechanisms and endpoints for phase II trials. *Nutr Rev.*,2004;62:204-211. 10.1111/j.1753-4887.2004.tb00041.x.
- Weisburger JH. Approaches for chronic disease prevention based on current understanding of underlying mechanisms. *Am J Clin Nutr.*,2000;71(6):1710S-1714S.
- Singh BN, Shankar S, Srivastava RK. Green Tea Catechin, Epigallocatechin-3-Gallate (EGCg), Mechanisms, Perspectives and Clinical Applications. *Biochem. Pharmacol.*,2011;82:1807–1821.
- Zhu H, Ye Y, He H, Dong C. Evaluation of green tea sensory quality via process characteristics and image information. *Food and Bioproducts Processing.*,2017;102:116-22. <http://www.adaigo.com/green/sencha.Html>
- Graham HN. Green tea composition, consumption, and polyphenol chemistry. *Prev. Med.*,1992;21:334–350.
- Bernatoniene J, Kopustinskiene DM. The Role of Catechins in Cellular Responses. *Molecular*,2018;23:965.
- Ye Y, Yan J, Cui J, Mao S, Li M, Liao X. *et al.* Dynamic changes in amino acids, catechins, ca_eine and gallic acid in green tea during withering. *J. Food Compos Anal*,2018;66:98–108.
- Soni RP, Katoch M, Kumar A, [...]. Tea: Production, composition, consumption its Potential an Antioxidant Antimicrobial agent. *Int. J. Food. Ferment. Technol.*,2015;5(2):95-106.
- Chacko SM, Thambi PT, Kuttan R, Nishigaki I. Beneficial effects of green tea: A literature review. *Chinese Medicine*, 2010.
- Sano M, Tabata M, Suzuki M, Degawa M, Miyase T, Maeda-Yamamoto M. *et al.* Simultaneous determination of twelve tea catechins by high-performance liquid chromatography with electrochemical detection. *Analyst*,2001;126:816-820. 10.1039/b102541b.
- Khokhar S, Magnusdottir SGM. Total phenol, catechin, and caffeine contents of teas commonly consumed in the United Kingdom. *J Agric Food Chem*,2002;50:565-570. 10.1021/jf0101531.
- Belitz DH, Grosch W. *Qui'mica de los Alimentos.*,1997.
- Graham HN. Green tea composition, consumption, and polyphenol chemistry. *Prev Med*,1992;21:334-350. 10.1016/0091-7435(92)90041-F.
- Vinson JA. Black and green tea and heart disease: a review. *Biofactors.*,2000;13:127-132. 10.1002/biof.5520130121.
- Sano M, Tabata M, Suzuki M, Degawa M, Miyase T, Maeda-Yamamoto M. *et al.* Simultaneous determination of twelve tea catechins by high-performance liquid chromatography with electrochemical detection. *Analyst*,2001;126:816-820. 10.1039/b102541b.
- Tadano N, Du C, Yumoto F, Morimoto S, Ohta M, Xie M, *et al.* Biological Actions of Green Tea Catechins on Cardiac Troponin C. *Br. J. Pharmacol*, 2010.
- Pharn-Huy L, He H, Phamhuy C. Green tea and health: an overview. *J Food Agric Environ*,2008;6:6–13.
- Miyazawa T. Absorption, metabolism and antioxidative effects of tea catechin in humans. *Biofactors*,2000;13:55–59.
- Manach C, Williamson G, Morand C, *et al.* Bioavailability and bioefficacy of polyphenols in humans. I. Review of 97 bioavailability studies. *Am J Clin Nutr*,2005;81:230S–242S.
- Botten D, Fugallo G, Fraternali F, Molteni C. Structural Properties of Green Tea Catechins. *J. Phys. Chem.B*,2015;119:12860–12867.
- Jigisha A, Nishant R, Navin K. Green tea: A magical herb with miraculous outcomes. *Int. Res. J. Pharm*, 2012.
- Schulze J, Melzer L, Smith L, Teschke R. Green Tea and Its Extracts in Cancer Prevention and Treatment. *Beverages*,2017;3:17.
- Fujioka K, Iwamoto T, Shima H, Tomaru K, Saito H, Ohtsuka M, *et al.* The Powdering.
- Process with a Set of Ceramic Mills for Green Tea Promoted Catechin Extraction and the ROS Inhibition Effect. *Molecules*,2016;21:474.
- Koláčeková T, Kolofíková K, Sytařová I, Snopek L, Sumczynski D, Orsavová J. *et al.* Matcha Tea: Analysis of Nutritional Composition, Phenolics and Antioxidant Activity. *Plant Foods Hum. Nutr.*,2020;75:48–53.
- Nishitani E, Sagesaka YM. Simultaneous Determination of Catechins, Caffeine and Other Phenolic Compounds in Tea Using New HPLC Method. *J. Food Compos. Anal.*,2004;17:675–685.
- Chen Q, Zhao J, Guo Z, Wang X. Determination of caffeine content and main catechins contents in green tea (*Camellia sinensis* L.) using taste sensor technique and multivariate calibration. *Journal of Food Composition and Analysis*,2010;23(4):353-8.
- Viani R, Garatini S. The composition of coffee. Caffeine, Coffee and Health,1993:17–41.
- Wong M, Sirisena S, Ng K. Phytochemical profile of differently processed tea: A review. *Journal of Food Science*,2022;87(5):1925-42.

33. Kc Y, Parajuli A, Khatri BB, Shiwakoti LD. Phytochemicals and quality of green and black teas from different clones of tea plant. *Journal of Food Quality*,2020:2020(1):8874271.
34. Del Rio D, Rodriguez-Mateos A, Spencer JP, Tognolini M, Borges G, Crozier A. *et al.* Dietary (poly) phenolics in human health: structures, bioavailability, and evidence of protective effects against chronic diseases. *Antioxidants redox signaling*,2013:18(14):1818-92.
35. Panche AN, Diwan AD, Chandra SR. Flavonoids: an overview. *Journal of nutritional science*,2016:5:e47.
36. Rathee P, Chaudhary H, Rathee S, Rathee D, Kumar V, Kohli K. *et al.* Mechanism of action of flavonoids as anti-inflammatory agents: a review. *Inflammation Allergy-Drug Targets (Formerly Current Drug Targets-Inflammation Allergy)(Discontinued)*,2009:8(3):229-35.
37. Landete JM. Ellagitannins, ellagic acid and their derived metabolites: a review about source, metabolism, functions and health *Food Res Int*441150-11602011.,2011.
38. Landete JM. Ellagitannins, ellagic acid and their derived metabolites: a review about source, metabolism, functions and health. *Food Res Int*,2011:44:1150-1160.
39. Yashin AY, Nemzer BV, Combet E, Yashin YI. Determination of the chemical composition of tea by chromatographic methods: a review. *Journal of Food Research*,2015:4(3):56-87.
40. Shofi VE, Betari BK. Effect shading intensity on color, chemical composition, and sensory evaluation of green tea (*Camelia sinensis* var *Assamica*). *Journal of the Saudi Society of Agricultural Sciences*,2023:22(7):407-12.
41. Kaur L, Jayasekera S, Moughan PJ. Antioxidant quality of tea (*Camellia sinensis*) as affected by environmental factors. In *Processing and impact on antioxidants in beverages*,2014:121-129.
42. Van Dorsten FA, Daykin CA, Mulder TP, Van Duynhoven JP. Metabonomics approach to determine metabolic differences between green tea and black tea consumption. *Journal of agricultural and food chemistry*,2006:54(18):6929-38.
43. Lee KW, Lee HJ, Lee CY. Antioxidant activity of black tea vs. green tea. *The Journal of nutrition*,2002:132(4):785.
44. Hilal Y, Engelhardt U. Characterisation of white tea—Comparison to green and black tea. *Journal für Verbraucherschutz und Lebensmittelsicherheit*,2007:2(4):414-21.
45. Komes D, Horžić D, Belščak A, Ganić KK, Vulić I. Green Tea Preparation and Its Influence on the Content of Bioactive Compounds. *Food Res. Int*,2010:43:167-176.
46. Pastoriza S, Mesías M, Cabrera C, Rufián-Henares JA. Healthy Properties of Green and White Teas: An Update. *Food Funct*,2017:8:2650-2662.
47. Kuriyama S, Shimazu T, Ohmori K, *et al.* Green tea consumption and mortality due to cardiovascular disease, cancer, and all causes in Japan: the Ohsaki study. *JAMA*,2006:296(10):1255-1265.
48. Sun CL, Yuan JM, Lee MJ, *et al.* Urinary tea polyphenols in relation to gastric and esophageal cancers: a prospective study of men in Shanghai, China. *Carcinogenesis*,2002:23(9):1497-1503.
49. Gokulakrishnan A, Jayachandran Dare B, Thirunavukkarasu C. Attenuation of the Cardiac Inflammatory Changes and Lipid Anomalies by (-)-Epigallocatechin-Gallate in Cigarette Smoke-Exposed Rats. *Mol. Cell. Biochem*,2011:354:1-10.
50. Ritchie K, Carrière I, de Mendonca A, Portet F, Dartigues JF, Rouaud O, *et al.* The Neuroprotective Effects of Caffeine: A Prospective Population Study (the Three City Study). *Neurology*,2007:69:536-545.
51. Ullah F, Ali T, Ullah N, Kim MO. Caffeine Prevents D-Galactose-Induced Cognitive Deficits, Oxidative Stress, Neuroinflammation and Neurodegeneration in the Adult Rat Brain. *Neurochem. Int*,2015:90:114-124.
52. Shimizu M, Fukutomi Y, Ninomiya M, Nagura K, Kato T, Araki H, *et al.* Green Tea Extracts for the Prevention of Metachronous Colorectal Adenomas: A Pilot Study. *Cancer Epidemiol. Biomark. Prev*,2008:17:3020-3025.
53. Salameh A, Dhein S, Mewes M, Sigusch S, Kiefer P, Vollroth M, *et al.* Anti-Oxidative or Anti-Inflammatory Additives Reduce Ischemia/Reperfusion Injury in an Animal Model of Cardiopulmonary Bypass. *Saudi J. Biol. Sci*,2020:27:18-29.
54. Ritchie K, Carrière I, de Mendonca A, Portet F, Dartigues JF, Rouaud O, *et al.* The Neuroprotective Effects of Caffeine: A Prospective Population Study (the Three City Study). *Neurology*,2007:69:536-545.
55. Ullah F, Ali T, Ullah N, Kim MO. Caffeine Prevents D-Galactose-Induced Cognitive Deficits, Oxidative Stress, Neuroinflammation and Neurodegeneration in the Adult Rat Brain. *Neurochem. Int*,2015:90:114-124.
56. Sinija VR, Mishra HN. Green tea: Health benefits. *Journal of Nutritional Environmental Medicine*,2008:17(4):232-42.
57. Chu C, Deng J, Man Y, Qu Y. Green Tea Extracts Epigallocatechin-3-Gallate for Different Treatments. *Bio Med Res. Int*,2017:2017:5615647.
58. Nagai K, Jiang MH, Hada J, Nagata T, Yajima Y, Yamamoto S, *et al.* (-) Epigallocatechin gallate protects against NO stress-induced neuronal damage after ischemia by acting as an anti-oxidant. *Brain Research*,2002:956(2):319-322.
[https://doi.org/10.1016/S0006-8993\(02\)03564-3](https://doi.org/10.1016/S0006-8993(02)03564-3).
59. Kim IB, Kim DY, Lee SJ, Sun MJ, Lee MS, Li H, *et al.* Inhibition of IL-8 production by green tea polyphenols in human nasal fibroblasts and A549 epithelial cells. *Biological and Pharmaceutical Bulletin*,2006:29(6):1120-1125.
60. Tang Y, Matsuoka I, Ono T, Inoue K, Kimura J. Selective up-regulation of P2X4-receptor gene expression by interferon- γ in vascular endothelial cells. *Journal of Pharmacological Sciences*,2008:107(4):419-427.
61. Rice-Evans CA, Miller NJ, Paganga G. Structure-antioxidant activity relationships of flavonoids and phenolic acids. *Free Radical Biology and Medicine*,1996:20(7):933-956.
62. Elbling L, Weiss RM, Teufelhofer O, *et al.* Green tea extract and (-)-epigallocatechin-3-gallate, the major tea catechin, exert oxidant but lack antioxidant activities. *The FASEB Journal*,2005:19(7):807-809.
63. Friedman SL. Cytokines and fibrogenesis. *Seminars in Liver Disease*,1999:19(2):129-140.

64. Goo HC, Hwang YS, Choi YR, Cho HN, Suh H. Development of collagenase-resistant collagen and its interaction with adult human dermal fibroblasts. *Bio materials*,2003;24(28):5099–5113.
65. Madhan B, Krishnamoorthy G, Rao JR, Nair BU. Role of green tea polyphenols in the inhibition of collagenolytic activity by collagenase. *International Journal of Biological Macromolecules*,2007;41(1):16–22.
66. Cho AR, Kim JH, Lee DE, *et al.* The effect of orally administered epigallocatechin-3-gallate on ligature-induced periodontitis in rats. *Journal of Periodontal Research*,2013;48(6):781–789.
67. Zhang H, Liu J, Lv Y, Jiang Y, Pan J, Zhu Y, *et al.* Changes in Intestinal Microbiota of Type 2 Diabetes in Mice in Response to Dietary Supplementation With Instant Tea or Matcha. *Can. J. Diabetes*,2020;44:44–52.