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GREEN TEA (*CAMELLIA SINENSIS*) AND ITS ANTIOXIDANT PROPERTY: A REVIEW

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Camellia sinensis, EC, ECG, EGC, EGCG, Antioxidants, Free Radicals

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ABSTRACT: Tea (*Camellia sinensis*) is one of the most widely consumed beverages in the world. Tea extracts are source of polyphenols, which are antioxidant components. Green tea phenolic compounds are predominately composed of catechin derivatives, although other compounds such as flavonols and phenolic acids are also present in lower proportion. The main catechin compounds found in green tea are (-) Epigallocatechin Gallate (EGCG), (-) Epigallocatechin (EGC), (-) Epicatechin Gallate (ECG) and (-) Epicatechin (EC) and other compounds. An antioxidant is a molecule capable of inhibiting the oxidation of other molecules. Oxidation is a chemical reaction that transfers electrons from the substance to an oxidizing agent. Oxidation reactions can produce free radicals. A molecule with one or more unpaired electron in its outer shell is called a free radical. Free radicals are formed from molecules *via* breakage of a chemical bond such that each fragment keeps one electron, by cleavage of a radical to give another radical and, also *via* redox reactions. In turn, these radicals can start chain reactions that damage cells. Antioxidants terminate these chain reactions by removing free radical intermediates, and inhibit other oxidation reactions. They do this by being oxidized themselves, so antioxidants are often reducing agents. Antioxidants play a significant role in our health. They are the compounds that protects cell against the damaging effect of reactive oxygen species. This review highlights the potentials of green tea with respect to its antioxidant constituents.

INTRODUCTION: Tea is one of the most widely consumed beverages in the world. Tea plant *Camellia sinensis* (family-Theaceae) has been originated from Southeast China, gradually expanded to India, Sri Lanka and further into many tropical and sub-tropical countries. The tea plant is grown in about 30 countries Worldwide. It grows best in tropical and subtropical areas with adequate rainfall, good drainage and slightly acidic soil.

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There are two varieties of tea. *Camellia sinensis* var. sinensis (China tea) is grown extensively in China, Japan, and Taiwan, while *C. assamica* var. assamica (Assam tea) predominates in south and south East Asia, including Malaysia and more recently, Australia [3].

Green tea is widely considered as a health-promoting beverage, and the beneficial effects generally associated with green tea have been attributed to its polyphenol content, particularly to catechins and their antioxidant activity. Green tea contains more catechins than black tea or oolong tea. Catechins are *in-vitro* and *in-vivo* strong antioxidants. In addition, its content minerals and Vitamins increase the antioxidant potential of this type of tea.

It is a widely used medicinal plant throughout India, China and popular in the various indigenous system of medicine like Ayurveda, Unani and Homoeopathy. Green tea has been consumed in all respective ages in India, China, Japan and Thailand. Green tea is believed to be a potent source of beneficial antioxidants, like that found in fruits and vegetables. Tea is particularly rich in polyphenols, including catechins, theaflavins and thearubigins, which are thought to contribute to the health benefits of tea [14].

Oxygen is an element indispensable for life. When cells use oxygen to generate energy free radicals are produced by the mitochondria. A free radical is defined as any chemical species that contains unpaired electron(s) in its outer orbit. They are formed from molecules via the breakage of a chemical bond such that each fragment keeps one electron, by cleavage of a radical to give another radical and, also *via* redox reactions. ROS (reactive oxygen species) and RNS (reactive nitrogen species) are the terms collectively describing free radicals and other non-radical reactive derivatives also called oxidants. Radicals are less stable than non-radical species, although their reactivity is generally stronger [4]. ROS/RNS are present in the atmosphere as pollutants and can be generated- [6, 33]

- During UV light irradiation, by X-rays and gamma rays,
- During metal catalyzed reactions,
- By neutrophils, esinophils and macrophages during inflammatory cell activation,
- As by-products of mitochondrial catalyzed electron transport reactions,
- By oxygen free radicals in the atmosphere considered as pollu-tants.
- In mitochondria-catalyzed electron transport reactions, oxygen free radicals produced as by product.
- By the metabolism of arachidonic acid, plate-lets, macrophages and smooth muscle cells.
- Interaction with chemicals, automobile exhausts fumes, smoking of cigarettes, cigars, beedie.
- Burning of organic matter during cooking, forest fires, volcanic activities.
- Industrial effluents, excess chemicals, alcoholic intake, certain drugs, asbestos, certain pesticides and herbicides, some met-al ions, fungal toxins and xenobiotics.
- By cytochrome P450 metabolism and the enzyme xanthine oxidase, which catalyzes the reaction of hypoxanthine to xanthine and xanthine to uric acid.

ROS and RNS includes radicals such as superoxide ($O2•^-$), hydroxyl (OH•), peroxyl (RO_2•), hydro-peroxyl (HO_2•), alkoxyl (RO•), peroxyl (ROO•), nitric oxide (NO•), nitrogen dioxide (NO_2•) and lipid peroxyl (LOO•); and non radicals like hydrogen peroxide (H_2O_2), hypochlorous acid (HOCl), ozone (O_3), singlet oxygen ($^1\Delta g$), peroxy-nitrate ($ONOO^-$), nitrous acid (HNO_2), dinitrogen trioxide (N_2O_3), lipid peroxide (LOOH) [4]. Free radicals cause damage to different levels in the cell: Attack lipids and proteins in the cell membrane so the cell cannot perform its vital functions (transport of nutrients, waste disposal, cell division, *etc*.) [31]. Free radicals generally involved in chain reactions, a series of reactions leads to regenerates a radical that can begin a new cycle of reactions. Free radical reactions take three distinct identifiable steps [9].

Initiation Step: Formation of radicals.

Propagation Step: In this step required free radical is regenerated repeatedly as a result of chain reaction, which would take the reaction to completion.

Termination Step: Destruction of radicals. Oxidation is a chemical reaction that transfers electrons from the substance to an oxidizing agent. Oxidation reactions can produce free radicals. In turn, these radicals can start chain reactions.

Antioxidants terminate these chain reactions by removing free radical intermediates, and inhibit other oxidation reactions. An anti-oxidant is a molecule capable of slowing or preventing the oxidation of other molecules. The term "anti-oxidant" also refers to any molecule capable of stabilizing or deactivating free radicals before they attack cells [5]. Antioxidants act as radical scavenger, hydrogen donor, electron donor, peroxide decomposer, singlet oxygen quencher, enzyme inhibitor, synergist and metal-chelating agents [37]. Anti-oxidants are important in living organisms as well as in food because they may delay or stop

formation of free radical by giving hydrogen atoms or scavenging them [31].

Classification of Antioxidants:

Based on Origin: [32]

Primary or Natural Antioxidants: They are the chain breaking antioxidants which react with lipid radicals and convert them into more stable products. Antioxidants of this group are mainly phenolic in structures and include the following:

Antioxidants Minerals: These are co factor of antioxidants enzymes. Their absence will definitely affect metabolism of many macromolecules such as carbohydrates. Examples include selenium, copper, iron, zinc and manganese.

Antioxidants Vitamins: It is needed for most body metabolic functions. They include Vitamin C, Vitamin E and Vitamin B.

Phytochemicals: These are phenolic compounds that are neither vitamins nor minerals. These include:

Flavonoids: These are phenolic compounds that give vegetables fruits, grains, seeds leaves, flowers and bark their colours.

Catechins: The most active antioxidants in green and black tea and sesamol.

Carotenoids: Fat soluble colour in fruits and vegetables.

Beta Carotene: Which is rich in carrot and converted to Vitamin A when the body lacks enough of the Vitamin.

Lycopene: High in tomatoes

Zeaxantin: High in spinach and other dark greens.

Herbs and Spices-source: Diterpene, rosmari-quinone, thyme, numeg, clove, black pepper, ginger, garlic and curcumin and derivatives.

Secondary or Synthetic Antioxidants: These are phenolic compounds that perform the function of capturing free radicals and stopping the chain reactions, the compound include:

Butylated Hydroxyl Anisole (BHA). Butylated hydroxyrotoluene (BHT).

Propyl gallate (PG) and metal chelating agent (EDTA).

Tertiary butyl hydroquinone (TBHQ).

Nordihydro guaretic acid (NDGA).

Based on Solubility: [10]

Hydrophilic Antioxidants: They are soluble in water. Water soluble antioxidants react with oxidants react with oxidants in the cell cytoplasm and blood plasma.

Hydrophobic Antioxidants: They are soluble in lipids. Lipid soluble antioxidants protect cell membranes from lipid peroxidation.

Based on Line of Defence: [10]

First Line Defence (Preventive Antioxidants): These are enzymes like superoxide dismutase (SOD), catalase (CAT), glutathione peroxidise (GTX), glutathione reductase and some minerals like Se, Mn, Cu *etc*. SOD mainly acts by quenching of superoxide (O_2), CAT by catalyzing the decomposition of hydrogen peroxide (H_2O_2) to water and oxygen. GTX catalyses the reduction of H_2O_2 and lipid peroxide generated during lipid peroxidation to water using reduced glutathione as substrate.

Second Line Defence (Radical Scavenging Antioxidant): These are glutathione, Vitamin C, uric acid, albumin, bilirubin, Vitamin E, carotenoids, flavonoid *etc*. β- carotene is an excellent scavenger of singlet oxygen.

Vitamin C interacts directly with radicals like O_2, OH. GSH is a good scavenger of many free radicals like O_2, OH and various lipid hydroperoxides and may help to detoxify many inhaled oxidizing air pollutants like ozone.

Third Line Defence (Repair and De-novo Enzyme): These are a complex group of enzymes for repair of damaged DNA, protein, oxidized lipids and peroxides and also to stop chain propagation of peroxyl lipid radical. These enzymes repair the damage to biomolecules and reconstitute the damaged cell membrane.

Based on Nature: [6, 7]

Enzymatic: Superoxide dimutase (SOD), Catalase (CAT) and Glutathione Peroxidise (GTX) *etc*.

Non Enzymatic: Ascorbic acid, tocopherols and tocotrienols, carotenoids, melatonin, polyphenols, thiol and bilirubin *etc*.

Free radicals oxidize many biological structures, damaging them. This is known as oxidative damage, a major cause of aging, cancer, athero-sclerosis, chronic inflammatory processes and cataracts, which are the most characteristic. In certain circumstances, production of free radicals can increase uncontrollably, a situation known as oxidative stress. This means "an imbalance between the speeds of production and destruction of toxic molecules, leading to an increase in cellular concentration of free radicals" [31] or "disharmony between ROS production and antioxidant numbers to scavenge ROS will increase oxidative stress".

Mechanism of Action of Antioxidants: Two principle mechanisms of action have been proposed for antioxidants [37, 38].

- The first is a chain- breaking mechanism by which the primary antioxidant donates an electron to the free radical present in the systems.
- The second mechanism involves removal of ROS/reactive nitrogen species initiators (secondary antioxidants) by quenching chain-initiating catalyst.
- Up-regulating or protecting antioxidant defences.
- Antioxidants may exert their effect on biological systems by different mechanisms including electron donation, metal ion chelation, co-antioxidants, or by gene expression regulation.

Tea's Profile: Tea is one of the most widely consumed beverages in the world today, second only to water, well ahead of coffee, beer, wine and carbonated soft drinks. The tea plant, *Camellia sinensis*, is a member of the Theaceae family and black, oolong and green tea are produced from its leaf and buds. It is an evergreen shrub or tree that can grow to a height of 30 feet, but is usually clipped to a height of 2.5 feet in cultivation. The tree or shrub is heavily branched with dark-green, hairy, oblong, ovate leaves cultivated and pre-ferentially picked as young shoots. Green tea is produced from steaming fresh leaves at high temperatures, thereby inactivating the oxidizing enzymes and leaving the polyphenol content intact [35]. Green tea is a 'non-fermented' tea and contains more catechins than black tea or oolong tea. Catechins are *in-vitro* and *in-vivo* strong antioxidants.

In addition, its content of certain minerals and Vitamins increases the antioxidant potential of this type of tea. Presently, it is cultivated in at least 30 countries around the world. Tea beverage is an infusion of the dried leaves of *Camellia sinesis*. It is a widely used medicinal plant by the trials throughout India, China and popular in various indigenous system of medicine like Ayurveda, Unani and Homoeopathy. Green tea has been consumed throughout the ages in India, China, Japan and Thailand [11].

TABLE 1: TAXONOMIC HIERARCHY OF *C. SINENSIS*

Kingdom	Plantae - plantes, Planta, Vegetal, plants
Sub Kingdom	Viridiplantae
Infra Kingdom	Streptophyta - land plants
Super Division	Embryophyta
Division	Tracheophyta - vascular plants, tracheophytes
Sub Division	Spermatophytina - spermatophytes, seed plants, phanérogames
Class	Magnoliopsida
Super Order	Asteranae
Order	Ericales
Family	Theaceae - tea
Genus	Camellia L. - tea
Species	*Camellia sinensis* (L.) Kuntze - tea

History: The plant *Camellia sinensis* was originally discovered and grown in Southeast Asia thousands of year ago and according to Chinese mythology, the emperor Shen Nung discovered tea for first time in 2737 BC [23]. The use of tea leaves probably first originated more than 3,000 years ago, in the southwest area of China and initially was used by people only for chewing and eating, in just the same way that coffee was first used [77]. Green tea has a long history as a folk remedy, and it is the most widely consumed beverage in the world but the beneficial medicinal properties have only been elucidated in the past 20 years [11]. Tea is grown mainly in the Subtropics and in the mountainous areas of the tropics between latitudes 41° N and 16° S. It is an intensively managed perennial monoculture crop cultivated on large- and small-scale plantations in a variety of countries including China, India, Sri Lanka, Kenya, Turkey, Vietnam, and Indonesia.

Types of Teas: [14]

Green Tea: It is prepared from unfermented leaves compared to the leaves of oolong tea which are partially fermented and black tea which are fully fermented. Green tea is rich in varieties of beneficial chemicals with maximum positive effects on human beings.

Black Tea: It accounts for approximately 72 % of the world's total tea production. While most of the EGCG antioxidants are oxidized during the fermenting process, black tea retains a high number of the antioxidants polyphenols such as flavonoids. These antioxidants help rid the body of harmful toxins.

White Tea: The buds and young tea leaves are collected shortly before the buds have fully opened. Then the leaves are steamed and dried with the minimum amount of processing. For this reason white tea retains the greatest levels of antioxidants and the lowest levels of caffeine than any other tea from the *C. sinensis* plant (green, black or oolong).

Oolong Tea: Oolong tea is a partially fermented tea and has the flavour and health characteristics of both green and black teas. It contains a high number of antioxidants, which protects healthy skin cells and the aging process slows down.

Pu'erh Tea: This type of tea comes from a large leaf variety of tea plant and can be picked any time of the year. Its processing is similar to that of black tea. What makes this tea unique is that once it is picked, it is piled and aged for as long as 50 - 100 years.

Roobios or Red Tea: It comes from a shrub in South Africa. It is naturally caffeine free– making it a good choice for pregnant or breastfeeding women. Rooibos or Red tea has a high number of antioxidants.

Green and oolong tea are more commonly consumed in Asian countries like India, China, Japan and Thailand, while black tea is most popular in Western countries. The more the leaves are fermented, the lower the polyphenol content, and the higher the caffeine content.

Chemical Composition: Green tea (prepared from processed leaves of *Camellia sinensis*) and its supplements generally contain higher amounts of disease fighting antioxidants called as polyphenols, 16 most of which are catechins. Catechins account for 10 % - 20 % of dry green tea leaves and those are described as being responsible for the bitter components of green tea. The major types of catechins in green tea are epigallocatechin gallate (EGCG), epigallocatechin (EGC), epicatechin (EC) and epicatechingallate (ECG), along with their heat-induced isomers that include catechin (+C), gallocatechin (GC), catechingallate (CG), and gallocatechingallate (GCG). Among these, EGCG has been extensively investigated since it is the dominant catechin in green tea [34].

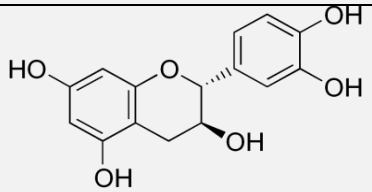
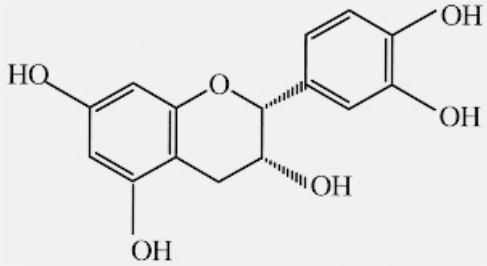
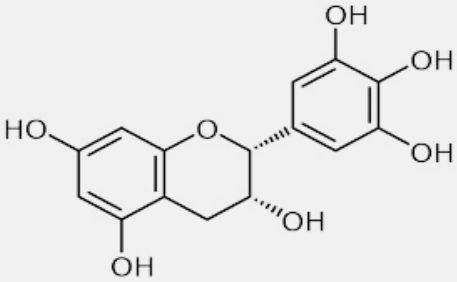
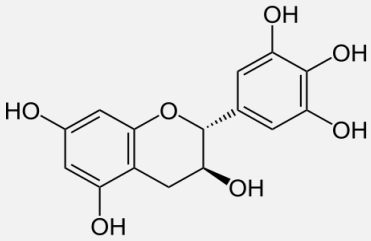
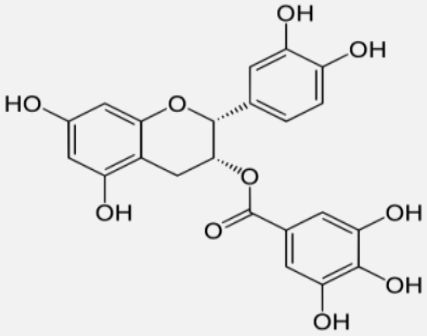
The chemical composition of green tea also includes: proteins (15-20% dry weight), whose enzymes constitute an important fraction; amino acids (1-4% dry weight) such as theanine or 5-N-ethylglutamine, glutamic acid, tryptophan, glycine, serine, aspartic acid, tyrosine, valine, leucine, threonine, arginine, 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 aluminum; and trace amounts of lipids (linoleic and α-linolenic acids), sterols (stigmasterol), Vitamins (B, C, E), pigments (chlorophyll, carotenoids) and volatile compounds (aldehydes, alcohols, esters, lactones, hydrocarbons). The fresh leaves contain, on average, 3-4 % of alkaloids known as methyl-xanthines, such as caffeine, theobromine and theophylline.

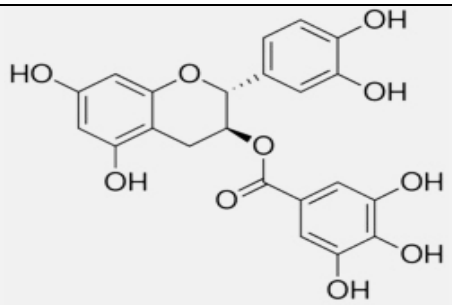
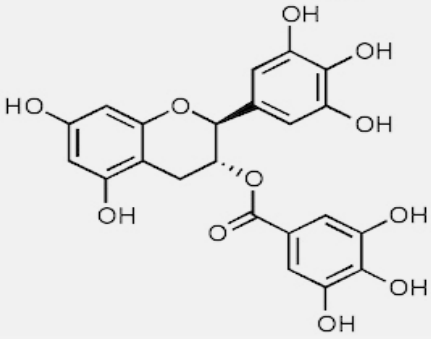
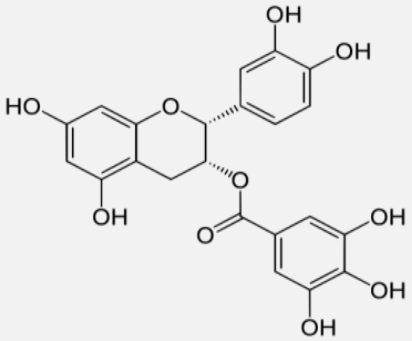
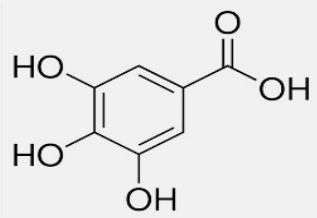
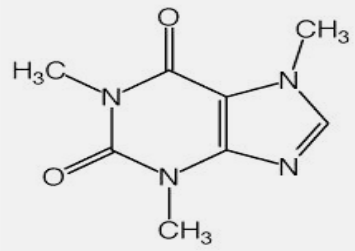
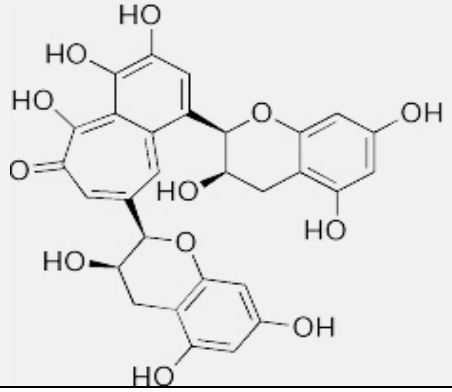
TABLE 2: PRIMARY CHEMICAL COMPOUNDS PRESENT IN TEA (ANALYZED BY CHROMATOGRAPHIC METHODS) [1]

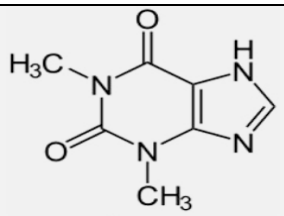
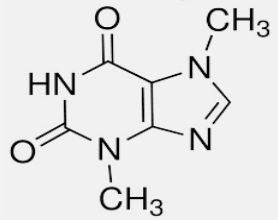
S. no.	Compound name	Main elements present
1	Catechins	Flavanols: 12 catechins are indentified, including 8 occurring in significant quantity, *i.e.*, (+)-catechin, (-)- epicatechin, (-)-gallocatechin, (-)-epigallocatechin, (-)-catechin gallate, (-)-epicatechin gallate, (-)-gallocatechin gallate, (-)-epigallocatechin gallate
2	Theaflavins	Theaflavin, theaflavin-3-O-gallate, theaflavin-3'-O-gallate, theaflavin-3-3'-O-gallate
3	Thearubigins	High-molecular weight polymers of catechin gallates with molecular weight from 1000 to 40000 Da

4	Alkaloids	Caffeine, theophylline, theobromine
5	Oxyaromatic Acids	Gallic, caffeic, quinine, chlorogenic, n-coumaric acids
6	Flavonols	Quercetin, kaempferol, myricetin
7	Teagallins	Teagallin
8	Pigments	Carotenoids and chlorophyll
9	Amino Acids	Isoleucine, leucine, methionine, threonine, phenylalanine, glutamine, asparagine, alanine, serine, proline, histidine, glutamic acid, aspartic acid, theanine
10	Sugars	Glucose, fructose, saccharose
11	Vitamins	Vitamins C, α-, β-, γ-, δ-tocopherols, riboflavin
12	Cations	K^+, Na^+,Ca^{2+}, Mg^{2+}, NH^{4+}, Al^{3+}
13	Dibasic Acids	Succinic, malic, tartaric, citric, quinic, aspartic, glutamic, oxalic acids
14	Metals	Fe, Zn, Cu, Ni, Al
15	Lignans and Triterpenoid Saponin	Mixture of many compounds

TABLE 3: CHEMICAL STRUCTURE

S. no.	Structure	Name	Formula
1		Catechin, C, (+)-Catechin	$C_{15}H_{14}O_6$
2		Epicatechin, EC, (-)-Epicatechin (cis)	$C_{15}H_{14}O_6$
3		Epigallocatechin, EGC, (-)-Epigallocatechin	$C_{15}H_{14}O_7$
4		Gallocatechin, GC, (+)-Gallocatechin	$C_{15}H_{14}O_7$
5		Epicatechin gallate, ECG, (-)-Epicatechin Gallate	$C_{22}H_{18}O_{10}$

6		Catechin gallate, CG, (+)- catechin gallate	$C_{22}H_{18}O_{10}$
7		Gallocatechin gallate, GCG, (+)- Gallocatechin gallate	$C_{22}H_{18}O_{11}$
8		Epigallocatechin gallate, EGCG, (-)-Epigallocatechin gallate	$C_{22}H_{18}O_{11}$
9		Gallic Acid	$C_7H_6O_5$
10		Caffeine	$C_8H_{10}N_4O_2$
11		Theaflavin	$C_{29}H_{24}O_{12}$

12		Thoephylline	$C_7H_8N_4O_2$
13		Theobromine	$C_7H_8N_4O_2$

Relationships between the Structure and Anti-oxidant Activity of Phenols: [36] The chemical activities of polyphenols in terms of their reducing properties as hydrogen - or electron donating agents predicts their potential for action as free radical scavengers (anti-oxidants). The activity of an antioxidant is determined by

- Its reactivity as a hydrogen or electron donating agent, which relates to its reducing potentials.
- The fate of the resulting antioxidant-derived radical, which is governed by its ability to stabilize or delocalize the unpaired electron.
- Its reactivity with other antioxidants.
- The transition metal-chelating potential.

Significance of Green Tea Antioxidants: Anti-oxidants present in green tea are responsible for several health benefits. Some of them are discussed below (also summarized in **Table 4**).

Green Tea in Systemic Health:

Anti-diabetic Effect: In Type II diabetes, which is a heterogeneous disorder, there is resistance of glucose and lipid metabolism in peripheral tissues to the biological activity of insulin and insulin secretion by pancreatic β cells is inadequate. In a study, administration of Green Tea polyphenols (500 mg/kg) to normal rats, there was an increase in glucose tolerance significantly at 60 minutes. Serum glucose levels was also reduced in alloxan diabetic rats at a dose of 100 mg/kg. For 15 days continuous administration of the green tea extract at 50 or 100 mg/kg daily, it produced 29% and 44% reduction, respectively, in the elevated serum glucose level produced by alloxan administration [40]. Green tea improves lipid and glucose metabolism, prevents sudden increase in blood sugar levels and balances our metabolic rate. The effects of tea on diabetes have received increasing attention. Tea catechins, especially EGCG, appear to have antidiabetic effects [80].

Antiparkinson Effect: Parkinson's disease is a progressive, degenerative disorder of the central nervous system, resulting from the loss of dopamine-producing brain cells, and there is presently no cure. Certain researchers have indicated that green tea possesses neuroprotective effects, suggesting its role in the prevention of Parkinson's disease. The authors discovered that green tea polyphenols protect dopamine neurons, which increases with the amount of green tea consumed. They also stated that this protective effect is mediated by inhibition of the ROS-NO pathway, a pathway that may contribute to cell death in Parkinson′s [78]. Antioxidants in green tea help prevent against cell damage in the brain, which could cause parkinson′s, and thus prevent it.

Antialzheimer Effect: In an *in-vitro* study, it was found that green tea inhibited human acetyl-cholinesterase, with an IC value of 0.03 mg/ml and, at an assay concentration of 0.03 mg/ml, inhibited β-secretase by 38%. These findings suggest that tea infusion contains biologically active principles, perhaps acting synergistically, that may be used to retard the progression of disease assuming that these principles reach the brain [79]. EGCG decreases production of beta-amyloid, a protein that forms the plaques that clog the brains of Alzheimer's victims. The primary target for treatment of Alzheimer's disease is inhibition of enzyme acetylcholinesterase and β-amyloidosis.

Antiobesity Effect: Obesity and overweight are rapidly growing, recognized medical problem in developed countries and is a threat to the health of large number of populations. The effects of tea on obesity have received increasing attention. Tea catechins, especially EGCG, appear to have anti-obesity effects [80]. Green tea is also seen as a natural herb that can enhance energy expenditure and fat oxidation and thereby induce weight loss. In a randomized, double-blind, placebo-controlled, cross-over pilot study, six overweight men were given 300 mg EGCG per day for two days. Fasting and postprandial changes in energy expenditure and substrate oxidation were assessed.

Resting energy expenditure did not differ significantly between EGCG and placebo treatments, although during the first postprandial monitoring phase, respiratory quotient values were significantly lower with EGCG treatment compared to the placebo. These findings suggest that EGCG alone has the potential to increase fat oxidation in men and may thereby contribute to the anti-obesity effects of green tea [81].

In Cardiovascular Disease: Cardiovascular disease (CVD) is a complex disorder involving multiple factors. Among those factors are inflammation, oxidative stress, platelet aggregation, and lipid metabolism. Some of these factors are also involved in other disease processes, but will be discussed in this paper under CVD. There have been a number of studies over the years assessing green tea consumption in respect to CVD risk [52]. Consumption of green tea is associated with lower risk of heart disease and stroke. Research published by Harvard demonstrates that people who drink at least one cup of tea daily have a 44 percent lower risk of heart attack. Green tea also dramatically increases the antioxidant capability of blood, which protects the LDL cholesterol particles from oxidation, which is one part of pathway towards heart disease. Women who consumed five or more cups per day had 31 % lower risk of dying from cardiovascular disease and stroke [82].

Anti-microbial Effect: A large amount of research has been performed assessing the antimicrobial scope of green tea catechins. Organisms affected by green tea include a large number of Gram-positive and Gram-negative aerobic bacteria, anaerobic bacteria, viruses, fungi, and at least one parasite. Among the antimicrobial mechanisms that have been attributed to green tea are: damage to the bacterial cell membrane, inhibition of bacterial fatty acid synthesis, inhibition of other enzymes (*e.g*., protein tyrosine kinase, cysteine proteinases, DNA gyrase, ATP synthase), and inhibition of efflux pump activity [83].

Anti-viral Effect: EGCG and ECG were found to be potent inhibitors of influenza virus replication in cell culture. This effect was observed in all influenza virus sub-types tested, including A/H_1N_1, A/H_3N_2 and B virus. Quantitative analysis revealed that, at high concentration, EGCG and ECG also suppressed viral RNA synthesis in cells, whereas EGC failed to show a similar effect. Similarly, EGCG and ECG inhibited the neuraminidase activity more effectively than the EGC. Neuraminidase is an antigenic glycoprotein enzyme found on the surface of the influenza virus. Neuraminidase has functions that aid in the efficiency of virus release from cells [86].

Antithyroidal Effect: GTE at relatively high doses caused hypothyroidism in rats by altering morphological and functional status of thyroid. Moreover, the commercially available catechins have shown pronounced effect inducing hypo-thyroidism which validates that the effect of GTE may be due to antithyroidal or goitrogenic effect of catechins present in tea. All these suggest that catechin present in green tea has the antithyroidal as well as goitrogenic potential and its regular consumption at relatively high doses pose a threat to the functioning of thyroid [84].

Tea and Bone Density: An interesting study of 1256 women in the United Kingdom ages 65-76 (1134 tea drinkers and 122 non-tea drinkers) reported that the tea drinkers had significantly greater mean bone mineral density (BMD) measurements (approximately 5%, adjusted for age and body-mass index), independent of smoking status, use of hormone-replacement therapy, coffee drinking, and whether milk was added to tea. Older women who drank tea had higher BMD measurements than did older women who did not drink tea [91].

Anti-cancer or Chemopreventive Effect: Scientific studies suggest that epigallocatechin gallate (EGCG), the major tea polyphenol along with other polyphenols have anti inflammatory and anti-cancer properties that may help prevent the onset and growth of skin tumours [85]. One population-based study found that Okinawan tea (similar to green tea but partially fermented) was associated with decreased lung cancer risk, particularly among women. Researchers found that women who consumed the most green tea experienced the least spread of cancer (particularly pre-menopausal women with early stages of breast cancer). However, women with late stages of breast cancer experienced little or no improvement from drinking green tea [14].

Anti-cataract Effect: Green tea also possesses its effect on eye with respect to cataract. Tea, administered in culture to enucleated rat lens, reduced the incidence of selenite cataract *in-vivo*. The study demonstrated that there was positive modulation of biochemical parameters in the organ culture study. The results indicated that tea act primarily as anti-cataract by preserving the anti-oxidant defense system [28].

In Arthritis: An antioxidant-rich polyphenolic fraction isolated from green tea has been reported to have anti-inflammatory properties in laboratory animals. One such study 17 reported positive benefits on collagen-induced arthritis in mice. The mice exhibited a significant reduction in the incidence of arthritis (33%-50%), compared with mice not given green tea polyphenols [90].

Green Tea in Oral Health:

Anti-cariogenic Effect: The effects of green tea extract on caries inhibition of hamsters and on acid resistance of human tooth enamel have been suggested by both *in-vivo* and *in-vitro* studies. The dialyzed tea solution in which the fluoride was removed almost completely also showed remarkable effects, similar to the original tea extract. The results obtained from this study suggested that fluoride in green tea may play a role in increasing the cariostatic action along with other components in tea. However, the action of fluoride does not seem to be so important because its concentration is very low. The effect of green tea on caries inhibition as well as on the increment of acid resistance appears to be more correlative with the nondialysable substances in tea [88].

In Halitosis: Halitosis is caused mainly by volatile sulfur compounds (VSCs) such as H_2S and CH_3SH produced in the oral cavity. Oral microorganisms degrade proteinaceous substrates to cysteine and methionine, which are then converted to VSCs. Because tea polyphenols have been shown to have antimicrobial and deodorant effects, researchers investigated whether green tea powder reduces VSCs in mouth air, and compared its effectiveness with that of other foods that are claimed to control halitosis. Immediately after administering the products, green tea showed the largest reduction in concentration of both H_2S and CH_3SH gases, especially CH_3SH, which also demonstrated a better correlation with odour strength than H_2S; however, no reduction was observed at 1, 2 and 3 h after administration.

In an *in-vitro* study, toothpaste, mints and green tea strongly inhibited VSCs production in a saliva-putrefaction system, but chewing gum and parsley-seed oil product could not inhibit saliva putrefaction. Toothpaste and green tea also demonstrated strong deodorant activities Therefore, it was concluded that green tea was very effective in reducing oral mal-odour temporarily because of its disinfectant and deodorant activities, whereas other foods were not effective [89].

Green Tea in Cosmetology:

Effect on Skin: Tea is used as an age-old home remedy for burns, wounds and swelling. A poultice of green tea eases itching and inflammation of insect bites, while a compress stems bleeding. Tannins and flavonoides of tea are having with the antiseptic properties. The former also have anti-inflammatory effects. Green tea also has some benefits for the body if used externally. It can be used to stop or slow bleeding, and can relieve itchy rashes and bug bites. Also, many hair and skin care products make use of tea tree oil to add shine and replenish. Researchers are also looking into green tea as a natural sun block. Green tea constituents may be useful topically for promoting skin regeneration, wound healing, or treatment of certain epithelial conditions such as aphthous

ulcers, psoriasis, rosacea, and actinic keratosis. At certain concentrations, EGCG or a mixture of the major green tea polyphenols stimulated aged keratinocytes to generate biological energy and to synthesize DNA, possibly for renewed cell division. Scientific studies suggest that epigallo-catechin gallate (EGCG), the major tea polyphenol along with other polyphenols have anti inflammatory and anti-cancer properties that may help prevent the onset and growth of skin tumours [85]. Research using pooled human keratinocytes (skin cells) to study the normal growth of the skin cells alone and comparing it to the growth of the cells when exposed to EGCG revealed that EGCG reactivated dying skin cells. Cells that migrate toward the surface of the skin normally live about 28 days and, by day 20, they sit on the epidermis getting ready to die and slough off. Current research seems to show that EGCG reactivates epidermis cells [87].

Anti-dandruff Effect: As the epidermal layer continually replaces itself, cells are pushed outward where they eventually die and flake off. In most people, these flakes of skin are too small to be visible. The result is that dead skin cells are shed in large, oily clumps, which appear as white or grayish patches on the scalp, skin and clothes that is popularly known as dandruff. Green tea naturally exfoliates the dry flakes which are the root of dandruff without dehydrating the skin. The researchers performed tests on an animal model to study the inflammatory skin diseases, characterized by patches of dry, red, flaky skin due to inflammation and overproduction of skin cells.

A study demonstrated that animals treated with green tea displayed slower growth of skin cells and the activation of a gene controlling the cells life cycles. Recent green tea and hair research shows that green tea is also good for your scalp. Green tea appears to normalize the skin cell growth cycle by regulating a protein called Caspase-14, which tells skin cells when to multiply and when to die off. Green tea has also been shown to soothe skin and reduce inflammation.

TABLE 4: SUMMARY OF HEALTH BENEFITS OF GREEN TEA

S. no.	Beneficial Effect	References
1	Anti-diabetic Activity	39 - 42, 51, 58
2	Anti-parkinson Activity	62, 78,
3	Anti-alzheimer Activity	55, 56, 62,
4	Anti-obesity Activity	43, 58, 80, 81
5	In Cardiovascular disease	22, 52, 59, 61, 82,
6	Smooth-muscle relaxant Activity	47;
7	Anti-microbial Activity	52, 71, 83,
7	Anti-viral Activity	86,
8	Skin Protective Activity	66,
8	Anti-inflammatory Activity	44, 48, 52,
9	Anti-allergic Activity	67,
10	Eye Protective Activity	70,
11	Renal Protective Activity	68, 69,
12	Anti-cancer Activity / Chemopreventive Activity	14, 23, 45, 50, 52, 54, 60, 63; 64, 75,
13	Anti-hair fall Activity	49
14	Oral Benefits	29, 52, 53, 73, 74,
15	Anti-lipidemic Activity	46, 59, 61,
16	Spatial Cognition Learning Ability	57,
17	Anti-thyroidal Effect	84,
18	Anti-ageing Activity	72,
19	In Brain Conditions / Functioning	65,
20	Green tea in cosmetology	85, 87,

CONCLUSION: Green tea is consumed throughout the world in various forms. The years of safe consumption of this beverage, supported by numerous studies showing health benefits, warrant a general recommendation to consume it regularly. It possess antioxidant, antidiabetic, anti-inflammatory, antibacterial, antiviral and above all cancer protective properties. Green tea also acts

positively on neurodegenerative diseases such as Parkinson and Alzheimer disease. This article demonstrates the potentials of green tea with respect to its antioxidant constituents. Although the human clinical data is still limited, this article shows that green tea has its place in both the conventional and alternative medical communities.

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